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EDITED BY

PAUL C. FREER, M. D., PH. D.

WITH THE COÖPERATION OF

W. D. SMITH, PH. D.; ALVIN J. COX, PH. D.; H. D. GIBBS, B. S.
W. C. REIBLING, B. S.; NELLIE LOUISE COOK, B. L., M. A.

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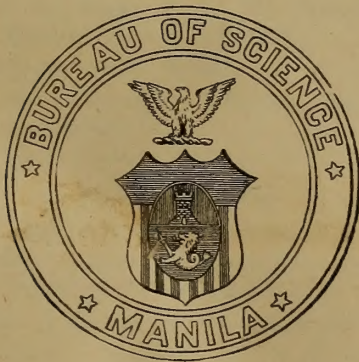
GOVERNMENT OF THE PHILIPPINE ISLANDS

A. CHEMICAL AND GEOLOGICAL SCIENCES AND
THE INDUSTRIES

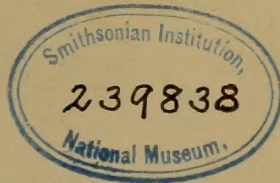
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WITH 82 PLATES, 37 TEXT FIGURES, AND 8 MAPS



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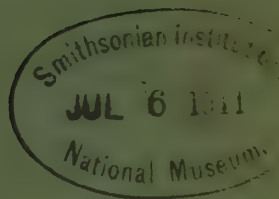
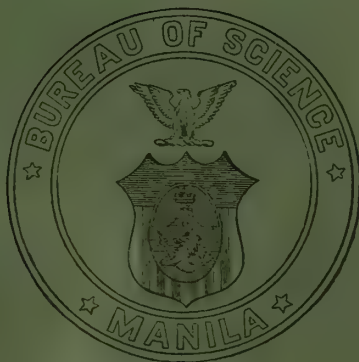
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THE PHILIPPINE JOURNAL OF SCIENCE

A. CHEMICAL AND GEOLOGICAL SCIENCES
AND THE INDUSTRIES

VOL. VI

JANUARY, 1911

No. 1

PHILIPPINE FIREWOOD.

By ALVIN J. COX.

(*From the Chemical Laboratory, Bureau of Science, Manila, P. I.*)

Very little has been done in a comparative study of the chemical and physical properties of Philippine woods. Many of them are quite different from those of the United States and other countries, where a great deal of work has been carried on, and without at least some preliminary data it is difficult to make any comparison. Much information may be gained from experience among those who have handled certain classes of wood for certain purposes. F. W. Foxworthy,¹ H. N. Whitford,² R. Gardner,³ W. M. Maule⁴ and others have published articles dealing with Philippine woods, and in order to connect these articles with the chemical technology of woods of other countries and to aid in the association of the fuel value of Philippine woods with well known ones, and perhaps their use in the charcoal industry, I have made the following investigation.

The greater proportion of the firewood of the Islands is cut from the trees which compose the thick mangrove swamps of the coast. Doctor Whitford,⁵ of the Bureau of Forestry, has estimated the area of these

¹ *This Journal*, Sec. C (1907), 2, 351; *Ibid.* (1909), 4, 409.

² *Bull. P. I. Bur. Forestry* (1907), No. 7.

³ *Loc. cit.* (1907), No. 4.

⁴ *The Charcoal Industry Loc. cit.* (1906), No. 2.

⁵ *Forests of the Philippines, Bull. P. I. Bur. Forestry* (1911), No. 10, p. 17.

swamps at 2.0 per cent of the public forests of the Philippine Islands, or 207,200 hectares; he further estimates the stand at about 20 cubic meters per hectare, or 4,144,000 cubic meters. They occur as narrow fringes along the coast, or to a considerable extent on the tidal flats at the mouths of the larger rivers, especially at the heads of bays. Perhaps all of the species of the *Rhizophoraceæ* are to be found in these swamps, although the general terms of *bacauan* and *tañgal* are often applied.⁶ Firewood is usually cut into two sizes called *leñas* and *rajas*. The former are seldom over one-half meter long and 7 or 8 centimeters in diameter, while the latter are about 1½ meters long and not over 15 centimeters in thickness. During the fiscal year 1909 taxes were paid on about 140,000 cubic meters of *leñas* and 11,500,000 *rajas*, making over 200,000 cubic meters in all. At least this amount is cut every year in the Philippines in vicinities with convenient transportation to markets, and more valuable firewood is left in the remote mangrove swamps after the removal of the tanbark. Most of the mangrove swamp trees used as fuel in the Philippines will yield bark fairly rich in tannin and dyestuffs and to that extent are valuable for tanning and dyeing. However, at present the wood and bark are usually burned together. A knowledge of the extractive materials, turpentine, resin tar, gas, alcohol, acids, etc., of woods is extremely closely associated with their use as a fuel. Not all have been investigated as yet, but a list of the publications of this Bureau on these subjects is given.⁷ The pulping qualities of Philippine woods have also been studied⁸ to a certain extent.

⁶ Following is a list of the local names of trees mentioned in this paper with the name of the dialect in which they are used:

BACAUAN or BACAO (Tagalog).	TABIGUE (Visayan), NIGUE, NIGI (Tagalog).
TANGAL (Tagalog, Visayan).	TAMBU TAMBU (Moro)=Tabigue.
POTOTAN (Tagalog, Visayan).	PAGATPAT (Moro).
GUAVA (English) or GUAYABAS (Spanish).	LUMBAYAO (Moro).
AGOHO (Tagalog, Ilocano, Visayan).	BAYUE (Moro), BAYOG (Tagalog).
BACAUAN TUBIG (Moro)=Pototan.	LENGGADI (Tagalog), HAGALAY, LANGARAY
CATUTAN (Moro)=Pototan.	(Visayan).

⁷ Bacon, R. F., and Gana, V. Q., The Economic Possibilities of the Mangrove Swamps of the Philippines, *This Journal*, Sec. A (1909), 4, 205; Editorial: Philippine Turpentine, *Ibid.* (1909), 4, 431; Brooks, B. T., The Oleoresin of *Pinus insularis* Endl., *Ibid.* (1910), 5, 229.

Mr. Williams, of the laboratory of organic chemistry of this Bureau, is now investigating the distillation of woods, but his report is not ready for publication.

⁸ Richmond, G. F., Philippine Fibers and Fibrous Substances: Their Suitability for Paper Making, *This Journal* (1906), 1, 433, 1075; *Ibid.*, Sec. A (1907), 2, 81; (1909), 4, 231; *Ibid.*, Sec. A (1910), 5, 233.

In order to make the following work available in connection with the tanbark industry, which is just in its infancy in these Islands, the wood and bark have in all cases been separated. The wood was sampled by collecting the sawdust from several crosscuts with a sharp saw. The bark was sampled first by breaking it into small pieces and quartering down to a few hundred grams, this was then ground and mixed until homogeneous. All of the work was done on air-dried samples. As oven-dried wood is very hygroscopic it was thought that perhaps equilibrium would be reached sooner and an air-dried sample more quickly prepared by first drying at 105° and then exposing to the laboratory air. In order to settle this point and the more accurately to define what "air-dried" might mean in the Philippines, the following experiments were carried on:

Three samples of wood (1) *Rhizophora mucronata* Lam. (bacauan) from the trunk of a tree about 30 centimeters in circumference, (2) *Bruguiera gymnorhiza* Lam. (pototan) from Lamao, Bataan, from the trunk of a tree about 40 centimeters in circumference, and (3) *Psidium guajava* L. (guava or guayabas), an introduced species, from a limb 30 centimeters in circumference taken from a tree near Manila, contained an amount of water equal to 22.8, 21.9 and about 18 per cent of the weight of the wood, respectively. Each sample was dried at 105°, all were simultaneously spread on a flat surface and exposed under identical laboratory conditions. They were analyzed from time to time with the following results:

TABLE I.

Time exposed.	Moisture.		
	Bacauan.	Pototan.	Guava.
Days.	Per cent.	Per cent.	Per cent.
0	0	0	0
3	11.73	11.54	11.55
6	11.74	11.91	12.42
9	12.73	12.55	13.12

Equilibrium was practically complete after three days, the fluctuations which followed being due for the greater part to variable humidity.

To ascertain whether or not the same equilibrium would be obtained by exposure to air, on the one hand of sawdust containing the original moisture of the green stick and on the other of a dried sample, the following experiment performed under identical conditions was carried on.

TABLE II.

Date.	Ex-posed.	Per cent of moisture.							
		Bacauan.				Pototan.			
		Air-dried. ^a		Dried at 105°.		Air-dried. ^b		Dried at 105°.	
	Days.	A.	B.	A.	B.	A.	B.	A.	B.
1909.									
Jan. 7	0	11.21	11.40	0.0	0.0	13.00	13.24	0.0	0.0
Jan. 29	22	11.23	11.31	10.33	10.28	12.43	12.41	10.79	10.73
Feb. 25	49	10.82		10.00		12.42		10.74	

^a This specimen was from the trunk of a tree 10 centimeters in diameter, and was collected on August 29, 1908. About November 1, when it arrived in my laboratory, it contained an amount of moisture equal to 33.07 per cent of the weight of the wood. On December 17, when it was sawed to secure the above sample, it contained 22.81 per cent. It was air-dried until December 29, when it contained 9.9 per cent, and was further air-dried until this experiment was begun.

^b On December 17, 1908, when this sample was sawed from the specimen, it contained an amount of moisture equal to 21.86 per cent of the weight of the wood. It was air-dried until December 29, when it contained 11.53 per cent, and again air-dried until January 7, 1910, when this experiment was begun.

It will be noticed that the moisture content of both of the above air-dried samples was less on December 29 than at any subsequent time, owing to a diminution of the humidity on the 28th and 29th to 76.8 and 76.6 per cent, respectively. The evaporation under shelter was 3.2 and 2.5 millimeters, respectively, on those days with an average of 2.1 millimeters for the month.⁹ The relative humidity on January 7 was 81.5 and on January 29 was 80.9, with an average of 80.8 for the month.¹⁰ During the ten days previous to February 25 the samples were shut in a tight room the relative humidity of which was but slightly lower than that of January 29.

The above experiment demonstrates that some change takes place during the drying at 105° that prevents the wood from regaining as much moisture from the air as it retains by air-drying. The amount of moisture still fluctuates with the humidity of the air, but the sample thus prepared always contains somewhat less than the air-dried one.

One of the most disturbing factors in the estimation of the value of a wood for fuel is the variable amount of water contained in it. It is a well-known fact that a specimen of air-dried wood always retains an amount of the water which was present in the green wood, the ultimate amount depending upon the atmosphere which surrounds it. It takes up water from or gives off water to the air until it reaches an equilibrium.

Rumford¹¹ found in Europe that sawdust on the average contained an amount of water in summer equal to about 9.3 per cent, in the autumn equal to about 12.3 per cent, and in the winter equal to about 19.6 per cent of the weight

⁹ *Bull. P. I. Weather Bur.* (1908), 484.

¹⁰ *Loc. cit.* (1909), 12.

¹¹ Nördlinger, H., *Technische Eigenschaften der Hölzer*, Stuttgart (1860), 113.

of the wood and assumed 11 per cent as the minimum hydrometric moisture in that climate.

In the Philippines, where the humidity is high and fairly regular, variation is much less than in countries where the climate is hot or cold, moist or dry, depending on the season. From the above and following results it will be seen that the water content seldom falls below 12.5 or 13.0 per cent of the weight of the dry wood, and it may be conjectured from the following, and also from unpublished analyses which I have made, that this may be a good average for thoroughly seasoned firewood. The moisture content of air-dried bark is about 14.5 per cent.

The moisture determinations in the above experiments as well as in the following ones were made by weighing a sample into a tared platinum crucible, drying in an oven at a temperature of 103° to 105°, after which it was cooled in a desiccator and weighed. The process was repeated until further drying showed very little loss in weight.

The ash was determined by carefully burning the organic matter of the wood with free access of air and weighing the residue. A discussion of this process will be found on page 10.

The dry weight is taken as the basis on which to compute the percentages of moisture and of ash. The advantage of computing percentages on this basis is that it furnishes a constant means of comparison, whereas if computed on the actual or wet weight the basis would vary with every change in the amount of moisture.

The determination of the calorific value of the wood was made in a Berthelot-Mahler bomb calorimeter under a pressure of 20 atmospheres of oxygen. The constants used were those which had been carefully determined for previous work and the corrections for wire fused, etc., were made according to the usual methods.¹²

The woods investigated are from various sources. Some of them were collected for me by Dr. H. N. Whitford, of the Bureau of Forestry, and by Dr. F. W. Foxworthy, of this Bureau, and the latter has made all of the botanical identifications. These, with such other information as I have at hand, are given below. The common name or the name under which the sample was received is given first, followed by the botanical name in parentheses.

Sample No. 1.—Agoho (*Casuarina equisetifolia* Forst.).

Sample No. 2.—Guava (*Psidium guajava* Linn.) an introduced species.

Sample No. 3.—Pototan (*Bruguiera gymnorrhiza* Lam.) from Lamao, Bataan.

Sample No. 4.—Bacauan (*Rhizophora mucronata* Lam.). Wood from the trunk of a tree about 15 centimeters in diameter.

Sample No. 5.—Bacao (*Rhizophora conjugata* Linn.).

¹² Cox, A. J., *This Journal*, Sec. A (1909), 4, 172.

Sample No. 6.—Bacauan tubig (*Bruguiera* sp.). No botanical material. Sapwood furnished to the United States department quartermaster for fuel at Zamboanga. Diameter of stick, 5 centimeters. Bark varies from 2.5 to 5 millimeters in thickness, with about equal parts of all three layers. The layers of bark succeeding one another from without inward adhere more closely. The epidermis adheres very loosely. Where the bark is thickest it is the most scaly and perhaps more decayed. The desiccated layers of bark are quite hard and still very brittle.

Sample No. 7.—Catutan (*Bruguiera* sp.) from Cotabato. Diameter of stick, 12.5 centimeters with heartwood beginning. Thickness and description of bark identical with No. 6.

Sample No. 8.—Tabigue (*Xylocarpus* sp.). Sapwood furnished to the United States department quartermaster for fuel at Zamboanga. Diameter of stick, 10 centimeters. Average thickness of bark, 1.5 millimeters, and there is very little variation. The bark is fairly smooth, the layers adhere closely and the epidermis and innermost layer are relatively thin. The dried bark is quite brittle.

Sample No. 9.—Bacauan (*Bruguiera* sp.). Sapwood furnished to the United States department quartermaster for fuel at Zamboanga. Diameter of stick, 7 centimeters. The bark varies from 3 to 4 millimeters in thickness, of which the epidermis, middle and inner layers have about the ratio 3 to 2 to 1, respectively. The three layers adhere fairly well, the epidermis the most loosely. The external appearance of the stick is somewhat smooth. The desiccated bark is hard and with the exception of the epidermis is quite brittle. The epidermis may be bent longitudinally almost at right angles before it will break.

Sample No. 10.—Tambu tambu (*Xylocarpus* sp.) from Cotabato. Diameter of stick, about 20 centimeters and the heartwood roughly equal to one-third of the cross section. The bark has a uniform thickness of about 2.5 millimeters, of which the epidermis, middle and inner layers have about the relative proportions 2 to 3 to 1, respectively. The desiccated layers of bark are hard, not very brittle and adhere closely.

Sample No. 11.—Pagatpat (*Sonneratia* sp.). Sapwood from Cotabato. No bark.

Sample No. 12.—Lumbayao (*Tarrietia javanica* Bl.). Second-class firewood from Camp Overton. Sapwood. No heart.

Sample No. 13.—Bayub (*Pterospermum* sp.). Sapwood from Mindanao.

Sample No. 14.—Bacauan (*Rhizophora conjugata* Linn.) from Mindanao. Collected for me by Dr. H. N. Whitford. Bureau of Forestry No. 11534.

Sample No. 15.—Tangal (*Ceriops tagal* (Perr.) C. B. Rob.) from Mindanao. As above. Bureau of Forestry No. 11535.

Sample No. 16.—Pototan (*Bruguiera gymnorrhiza* Lam.) from Mindanao. As above. Bureau of Forestry No. 11536.

Sample No. 17.—Lenggadi (*Bruguiera parviflora* W. & A.) from Mindanao. As above. Bureau of Forestry No. 11537.

Sample No. 18.—Pagatpat (*Sonneratia* sp.). Thoroughly seasoned wood from Palawan.

Sample No. 19.—Pagatpat (*Sonneratia* sp.). Unseasoned wood from Zamboanga, Mindanao.

Tables of analyses and calorific determinations of these woods are as follows:

TABLE III.—Analyses and calorific determinations of air-dried wood without bark.

No.	Common name.	Moisture.	Ash.	Main calories. ^a	Available heating value.	Heating value of combustible matter, wood—(water + ash) in main calories. ^a	Available heating value of combustible matter, wood—(water + ash).
		<i>Per cent.</i>	<i>Per cent.</i>		<i>Calories.</i>		<i>Calories.</i>
1	Agoho	{ 11.68	0.61	4,193	3,795	4,706	4,329
		{ 11.39	0.62				
2	Guaya	{ 13.12	1.31				
		{ 1.39					
3	Pototan	{ 13.01	1.46	4,180	3,833	4,798	4,480
		{ 13.26	1.44	4,191	3,829	4,793	4,475
4	Bacauan	{ 11.22	2.23	4,118	3,772	4,689	4,365
		{ 11.37	2.29	4,107	3,746	4,682	4,358
5	Bacao	{ 11.03	1.81	4,159	3,781	4,699	4,340
		{ 10.94	1.74				
6	Bacauan tubig	{ 13.21	5.75	3,753	3,366	(^b)	(^b)
		{ 5.57					
7	Catutan	{ 13.79	1.28	4,142	3,705	4,787	4,368
		{ 13.77	1.29				
8	Tabigue	{ 13.93	2.80	4,005	3,634	4,694	4,345
		{ 13.77	2.05	4,066	3,764	4,723	4,456
9	Bacauan	{ 13.39	2.12				
10	Tambu tambu	{ 12.99	2.72	4,162	3,873	4,833	4,578
		{ 12.99	2.71				
11	Pagatpat	{ 14.27	2.62	4,116	3,841	4,831	4,596
		{ 14.27	2.65				
12	Lumbayao	{ 12.84	1.44	4,203	3,803	4,812	4,432
13	Bayud	{ 13.03	1.46	4,252	3,891	4,877	4,542
14	Bacauan	{ 10.71	2.41	4,136	3,721	4,689	4,284
		{ 2.26		4,154	3,760	4,720	4,328
15	Tangal	{ 11.41	1.60	4,292	3,924	4,747	4,399
		{ 4.293		4,293	3,906	4,747	4,378
16	Pototan	{ 12.26	1.55	4,286	3,895	4,840	4,466
		{ 4.227		4,227	3,855	4,773	4,421
17	Lenggadi	{ 11.97	1.65	4,072	3,716	4,629	4,296
	Average of averages	{ 12.59				4,755	4,418

^a In the usual determination of the calorific value of a fuel in a calorimeter the products are cooled to the ordinary temperature and the result is therefore higher than can ever be realized in ideal practice, where the resulting gases always leave the flues at a temperature above 100°. Since the object of the determination of the calorific value of a fuel is to show its technical worth, I always have calculated the results on Philippine fuels on the assumption that the moisture present and the water formed during the combustion remain as steam at 100°, i. e., I have made a water correction by subtracting 6 calories for each per cent of water. Some mechanical engineers do not make this correction, and therefore obtain a result from 3 to 10 per cent too high, and in order that my results may be comparable in all cases I have decided to give also the uncorrected result under the caption "Main calories."

^b On account of the very high ash content and the possibility of error in its determination (cf. p. 10), this sample has little comparative value and I have therefore not included the heating value of the combustible matter in the average. The calculated results for the combustible matter, wood—(water + ash), in main calories and available calories are 4,482 and 4,123, respectively.

TABLE IV.—Analyses and calorific determinations of air-dried bark.^a

No.	Common name.	Moisture.	Ash.	Main calories. ^b	Available heating value.	Heating value of combustible matter, wood — (water + ash) in main calories. ^b	Available heating value of combustible matter, wood — (water + ash).
		<i>Per cent.</i>	<i>Per cent.</i>		<i>Calories.</i>		<i>Calories.</i>
2	Guava	12.41	11.80	3,522	3,199	4,475	4,153
3	Pototan	13.90	6.72	3,983	3,668	4,863	4,568
4	Bacauan	10.23	10.37	3,971	3,664	4,884	4,575
6	do	15.67	8.19	4,054	3,708	5,124	4,791
				4,034	3,692	5,099	4,771
7	Catutan	16.27	4.60	4,037	3,710	4,920	4,624
8	Tabigue	16.21	7.93	3,848	3,488	4,857	4,510
9	Bacauan	15.70	8.17	3,891	3,565	4,903	4,594
10	Tambu tambu	15.74	8.39	3,841	3,536	4,853	4,571
	Average of averages	14.52				4,858	4,547

^a One might surmise that the external configuration of the bark would have an influence on the extraneous matter.

^b See footnote "a" of Table III.

Table III shows that the average of the calorific values of the combustible matter of all the woods analyzed are practically the same. The same uniformity is shown in the ultimate composition of different woods.

TABLE V.—Ultimate composition of different dry woods.

Kind of wood.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Available calories.	Main calories.
<i>From F. Fischer.¹³</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per ct.</i>		
Oak	49.84	5.83	43.94		0.39	4,421	4,740
Spruce	50.05	6.04	43.21		0.70		4,892
Birch	48.45	5.95	45.26		0.34		4,805
Acacia	49.20	5.91	43.10		0.79		4,798
Beech	48.55	5.85	45.04		0.56		4,802
<i>From Chevandier.¹⁴</i>							
Red beech	49.89	6.07	43.11	0.93	(*)		
Oak	50.64	6.03	42.05	1.28			
Birch	50.61	6.23	42.04	1.12			
Aspen	50.31	6.32	42.39	0.98			
Willow	51.75	6.19	41.08	0.98			

^a Calculated free from ash.

¹³ *Ztschr. f. angew. Chem.* (1893), 6, 578, and (1899), 12, 334; J. (1900), 45, 5.

¹⁴ Nördlinger, *Technische Eigenschaften der Hölzer*, Stuttgart (1860), 415.

TABLE V.—Ultimate composition of different dry woods—Continued.

Kind of wood.	Carbon.	Hydrogen.	Oxygen.	Nitrogen.	Ash.	Available calories.	Main calories.
<i>From Gottlieb.¹⁵</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per ct.</i>		
Oak	50.22	5.99	43.42	0.09	0.28	-----	4,600
Ash	49.77	6.26	43.37	0.07	0.53	-----	4,710
Hornbeam	49.48	6.17	43.77	0.06	0.52	-----	4,730
Beech:							
130 years old	49.03	6.06	44.36	0.11	0.44	-----	4,790
100 years old	48.87	6.14	44.29	0.06	0.64	-----	4,770
60 years old	49.14	6.16	44.07	0.09	0.54	-----	4,760
Birch	48.88	6.06	44.67	0.10	0.29	-----	4,770
Fir	50.36	5.92	43.39	0.05	0.28	-----	5,025
Spruce	50.31	6.20	43.08	0.04	0.37	-----	5,080

The chemical composition of wood is very complex, as the material consists of both organic and inorganic bodies. The former are made up chiefly of cellulose and lignin which are more or less united with each other, together with the soluble and insoluble constituents of the dried sap, such as sugar, dextrin, starch, fibrin, albumin or other nitrogen-containing bodies, and often more or less tannin, dyes and different kinds of resin. The relative amounts of these present in different woods, or different parts of the same tree, vary or may vary with the age, condition of the growth and physiological processes that have taken place, the soil and physical conditions upon which and under which it is grown, the time of the year, etc. However, the fact remains that the principal compounds of all woods are the same, and those substances present in smaller quantities contain the same elements—carbon and hydrogen. It is the amount of carbon and the amount of hydrogen in excess of the equivalent amount of oxygen which determines the calorific value.

In general, the theoretical heating value of a fuel, i. e., the amount of heat produced by completely converting the carbon into dioxide and the hydrogen into water, without regard to the efficiency of the furnace in which it is consumed, may be calculated from its elementary analysis. The difference in the way that the carbon, hydrogen and oxygen are combined in the wood has no influence on the heating effect. The calculation concerns only their percentages. The greater part of the hydrogen is left in the form of water by the breaking down of the complex compounds and has no heating effect.

From the analysis of wood it might be expected that the calorific value of that part remaining after deducting the water and ash would be almost

¹⁵ *Journ. f. prakt. Chem. N. F.* (1883), 28, 385; *J. B.* (1886), 31, 355.

the same in all cases. It is not surprising then that there is no such great uniformity shown in the calorific values of the actual determinations.

Wood ash contains potassium, sodium, calcium and magnesium in large quantities, chiefly as carbonate, phosphate and sulphate; iron, alumina, chlorine and silica in smaller quantities. It would be noticed that the salt-water woods are quite high in chlorine. Analyses of the ash of Philippine woods follow:

TABLE VI.—*Analyses of the wood ash (bark excluded).*

(Numbers give percentages.)

Constituent.	Agoho.	Guava.	Pototan.	Bacauan.	Bacao.
Per cent of ash -----	0.61	1.35	1.45	2.26	1.78
Insoluble in water.					
Silica (SiO_2) -----	1.01	0.61	0.68	0.35	0.32
Alumina (Al_2O_3) -----	2.11	0.43	0.85	0.72	0.44
Ferric oxide (Fe_2O_3) -----	0.52	0.32	0.22	0.22	0.30
Lime (CaO) -----	30.58	22.75	15.14	32.82	36.28
Magnesia (MgO) -----	4.52	4.51	3.76	4.11	2.29
Potash (K_2O) and soda (Na_2O) -----	Trace.	None.	None.	None.	None.
Phosphoric anhydride (P_2O_5) -----	3.50	9.82	3.48	1.86	1.25
Sulphuric anhydride (SO_3) -----	None.	None.	None.	None.	None.
Chlorine (Cl) -----	None.	None.	None.	None.	None.
Carbon dioxide and undetermined -----	23.91	11.51	9.52	22.77	27.04
Total insoluble -----	66.15	49.95	33.65	62.85	67.92
Soluble in water.					
Silica (SiO_2) -----	Trace.	None.	None.	None.	None.
Alumina (Al_2O_3) and ferric oxide (Fe_2O_3) -----	None.	None.	None.	None.	Trace.
Lime (CaO) -----	0.74	0.39	0.21	1.47	1.27
Magnesia (MgO) -----	0.89	0.93	0.53	0.13	1.06
Potash (K_2O) -----	9.87	29.30	8.15	4.37	4.29
Soda (Na_2O) -----	10.73	2.30	30.86	15.87	12.02
Phosphoric anhydride (P_2O_5) -----	Trace.			Trace.	Trace.
Sulphuric anhydride (SO_3) -----	2.96	1.61	5.85	1.16	4.71
Chlorine (Cl) -----	0.74	0.71	5.71	4.38	0.34
Carbon dioxide and undetermined -----	7.92	14.81	15.04	9.77	8.39
Total soluble -----	33.85	50.05	66.35	37.15	32.08

Analyses of the residue which remains when woods are burned are very important in determining the relationship of wood growth to the mineral constituents of the soil and are useful for certain technical dispositions of the ash, but give little clue to the combinations or even the weight of the inorganic matter present in the original material.

The ash scarcely represents the mineral matter in the wood at all. Perhaps all of the carbon and sulphur of the carbonates and sulphates respectively were present in the organic acid radicals of metallic salts and have already contributed their share to the calorific value of the fuel, still their weight is deducted as inert matter. If the calcium were present as oxalate it would be just to deduct

the weight of carbonate as ash. Perhaps iron originally in the ferrous condition is oxidized to the ferric. All these things make the ash content high. On the other hand, there may be water which can not be expelled by drying at 105° and is still not retained as ash. Wood minus water and ash may be one thing for one wood and another for another. When the per cent of ash is large the error may be of considerable magnitude; I can not offer a method for the calculation of the amount. The uniformity in the calorific value of that part of the wood remaining after deducting the water and the ash might be increased were it possible to determine the extraneous mineral matter in the wood instead of that remaining after combustion.

The relation of the relative weight of wood to its everyday use is extremely important. The density is at the basis of its consumption in almost every enterprise. As wood for fuel is sold by measure, a knowledge of the relative weight is especially important.

This property is sometimes expressed in terms of cubic meters, but usually by specific gravity. The weight of any quantity of wood can be computed from these data. In general one thinks of the density of the wood fiber with its resin, coloring material, etc., as synonymous with specific gravity, but one can see at once that the wood cells sometimes contain a certain amount of air; and that the amount of air or water in the interstices might have a great deal to do with the latter. Bauschinger¹⁶ has shown the relation between the specific gravity and the percentage of moisture. "At first the specific gravity diminishes rapidly as the percentage of moisture is reduced, but when this has been reduced to 15 per cent the specific gravity changes very little for any further reduction in moisture. This shows that the shrinkage is insignificant until the timber becomes nearly dry, when it swells and shrinks almost directly with the percentage of moisture, so that the weight of a unit volume, which is a measure of the specific gravity, remains nearly constant."

Therefore it will be seen that the porosity or compactness of an air-dried wood with its respective amount of resin, coloring material, etc., is a direct function of its specific gravity and a variation of a few per cent in the water content within the above-named limits has no influence. The specific gravity of mineral matter is from 2.5 to 3.5, and therefore high ash would exert an influence on the specific gravity, but the percentage of ash in wood is usually so small as to be in general of little consequence.

There is no entirely satisfactory method of determining the volume of porous bodies like wood, but some means of immersion is unquestionably the best. I at first thought of using mercury, but this was given up because of the great difference in specific gravity between the mercury and the wood and furthermore because the hanging bubbles of air could not easily be seen. My method was as follows:

I used a cross section of the wood of the proper length and split from 2 to 4 pencil-shaped pieces from different parts so large that they would just enter a large-mouthed specific gravity bottle. The weight of the bottle with water at a

¹⁶ Fernow, B. E., *Timber Physics*, Pt. 1, U. S. Dept. Agr., *For. Div. Bull.* 6, 40; Report of Tests made at the Govt. Testing Laboratory at Munich 16.

given temperature was determined. Just before using, the weighed pieces of wood were dipped into distilled water, rubbed with a cloth or the fingers to remove the air bubbles, and placed immediately into the specific gravity bottle which was filled with water. The stopper was next inserted and the weight determined. From these data the specific gravity can be accurately computed. My results are as accurate as is possible to secure with small pieces as is shown by the fact that no perceptible amount of air escaped from the sample in the time required to complete the experiment. In order to make the data complete I have determined the specific gravity and the water content simultaneously on similarly prepared pieces as follows:

TABLE VII.—*Specific gravities of Philippine firewoods.*

No.	Common name.	Moisture.	Ash.	Specific gravity.
		<i>Per cent.</i>	<i>Per cent.</i>	
1	Agoho-----	(*)	{ 0.62 0.61	0.8569
2	Guaya-----	{ 13.46 13.19	1.39 1.31	0.7712 0.6973
3	Pototan-----	{ 13.58 13.51	1.46 1.44	0.7671 0.7441
4	Bacauan-----	{ ^b 12.10 ^a 11.46	2.29 2.23	^c 0.9861 ^c 0.9801
5	Bacao-----	{ ----- -----	1.81 1.74	----- -----
6	Bacauan-----	{ 12.26 11.88	5.75 5.57	0.8799 0.8732
7	Catutan-----	{ 13.24 13.03	1.29 1.28	0.9136 0.8868
8	Tabigue-----	{ 13.71 12.73	2.80 -----	0.7412 0.7333
9	Bacauan-----	{ 13.07 12.77	2.12 2.05	0.996 0.991
10	Tambu tambu-----	{ ^b 13.00 ^a 12.50	2.72 2.71	0.5954 0.5668
11	Pagatpat-----	{ 12.94 12.83	2.65 2.62	0.6688 0.5867
12	Lumbayao-----	{ 11.88 11.38	1.44 -----	0.5461 -----
13	Bayub-----	{ 12.85 12.84	1.46 -----	0.5062 0.4914
14	Bacauan-----	{ 12.78 12.45	2.41 2.26	^e 1.071 ^e 1.002
15	Tangal-----	{ 13.25 13.09	1.60 -----	0.890 0.880
16	Pototan-----	{ 13.24 12.63	1.55 -----	0.9426 0.9336
17	Lenggadi-----	{ 13.37 13.32	1.65 -----	0.8936 0.8881
18	Pagatpat-----	(*)	-----	0.8186
19	Pagatpat-----	(†)	-----	0.8447
	Average of averages-----	12.81	-----	-----

^a Air-dry.

^b Heartwood beginning to form.

^c The heartwood sinks.

^d Sapwood.

^e Heavier than water.

^f Unseasoned.

It will be seen that the calorific values of Philippine woods vary but little, not so much as would be anticipated from the presence of varying quantities of complex gums, resins and color substances. I have given the average heating value of the combustible matter of wood, wood—(water+ash), as 4,418 calories. The available heating value of any wood can be calculated approximately by first reducing the above value in proportion to the diluents, water and ash, and then subtracting a number of calories equal to 6 times the per cent of water in the sample, i. e.,

$$\text{Calories} = 4418 \times \left(\frac{100 - (\text{per cent water} + \text{per cent ash})}{100} \right) - 6 \times \text{per cent water.}$$

Aside from the percentage of water and ash, the chief factors controlling the selection of a firewood are physical, i. e., compactness or weight, as indicated by the specific gravity.

The fiber of all woods when finely powdered and completely dried has approximately a constant specific gravity of about 1.5. This shows that the weight of ordinary wood depends mainly upon two things—its compactness and its moisture, that the amount of woody fiber in woods containing the same amount of moisture is approximately proportional to the specific gravity, and that usually the best firewoods are those with very dense cell walls. Therefore, the fuel value of wood may be roughly classified on this basis as shown by the following tables of common North American woods¹⁷ and of some of the Philippine firewoods.

TABLE VIII.—Approximate fuel value of North American woods.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Poor (sp. gr., 0.25 to 0.45).	Cypress:		
	Bald cypress (<i>Taxodium distichum</i> Rich.)	0.454	Penhallow,* p. 217.
	Fir:		
	Balsam fir (<i>Abies balsamea</i> Mill.)	0.382	Penhallow, p. 258.
	White fir (<i>A. grandis</i> Lindl.)	0.354	Penhallow, p. 261.
	White fir (<i>A. amabilis</i> Forbes)	0.423	Penhallow, p. 260.
	Red fir (<i>A. nobilis</i> Lindl.)	0.456	Penhallow, p. 262.
	Red fir (<i>A. magnifica</i> A. Murr.)	0.470	Penhallow, p. 259.
	Hemlock (<i>Tsuga canadensis</i> Carr.)	0.424	Penhallow, p. 266.
	Hemlock (<i>T. mertensiana</i> Carr.)	0.518	Penhallow, p. 270.
	White cedar:		
	White cedar (<i>Thuja occidentalis</i> Linn.)	0.316	Penhallow, p. 221.
	Canoe cedar (<i>T. gigantea</i> Nutt.)	0.379	Penhallow, p. 221.
	White cedar (<i>Chamaecyparis thyoides</i> (Linn.) B. S. P.)	0.332	Penhallow, p. 231.
	White cedar (<i>C. lawsoniana</i> A. Murr.)	0.462	Penhallow, p. 232.
	White cedar (<i>Libocedrus decurrens</i> Torr.)	0.402	Penhallow, p. 219.
	Redwood (<i>Sequoia sempervirens</i> Endl.)	0.421	Penhallow, p. 224.
	Big tree (<i>S. gigantea</i> Decne.)	0.288	Penhallow, p. 225.

* Penhallow, D. P., North American Gymnosperms, Boston (1907).

¹⁷ The list of common woods was largely taken from U. S. Dept. Agr., *Div. For. Bull.* (1895), No. 10, 72.

TABLE VIII.—Approximate fuel value of North American woods—Continued.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Poor (sp. gr., 0.25 to 0.45).	Spruce:		
	Black spruce (<i>Picea nigra</i> Ait.) -----	0.459	Penhallow, p. 289.
	White spruce (<i>P. alba</i> Ait.) -----	0.405	Penhallow, p. 285.
	White spruce (<i>P. engelmanni</i> Engelm.) ---	0.345	Penhallow, p. 286.
	Tide-land spruce (<i>P. sitchensis</i> Carr.) ----	0.429	Penhallow, p. 290.
	Soft pines:		
	White pine (<i>Pinus strobus</i> Linn.) -----	0.385	Penhallow, p. 315.
	Sugar pine (<i>P. lambertiana</i> Douglas) -----	0.368	Penhallow, p. 312.
	White pine (<i>P. monticola</i> D. Don) -----	0.391	Penhallow, p. 312.
	White pine (<i>P. flexilis</i> James) -----	0.436	Penhallow, p. 313.
	Basswood (American linden):		
	Basswood (<i>Tilia americana</i> Linn.) -----	0.449	B. & B., ^a 2, p. 414.
	White basswood (<i>T. heterophylla</i> Vent.) --	0.417	B. & B., 2, p. 414.
	Buckeye (horse chestnut):		
	Ohio buckeye (<i>Aesculus glabra</i> Willd.) ----	0.449	B. & B., 2, p. 401.
	Sweet buckeye (<i>A. octandra</i> Marsh.) -----	0.433	B. & B., 2, p. 401.
	Butternut (<i>Juglans cinerea</i> Linn.) -----	0.401	B. & B., 1, p. 484.
	Catalpa (<i>Catalpa speciosa</i> Warder) -----	0.417	B. & B., 3, p. 200.
	Poplar (cottonwood):		
	Cottonwood (<i>Populus deltoides</i> Marsh.) (<i>P. monilifera</i> Ait.) -----	0.385	B. & B., 1, p. 498.
	Balsam (<i>P. balsamifera</i> Linn.) -----	0.369	B. & B., 1, p. 491.
	Poplar (<i>P. grandidentata</i> Michx.) -----	0.385	B. & B., 1, p. 492.
	Aspen (<i>P. tremuloides</i> Michx.) -----	0.401	B. & B., 1, p. 492.
	Willow:		
	Black willow (<i>Salix nigra</i> Marsh.) -----	0.449	B. & B., 1, p. 494.
	Peach-leaved willow (<i>S. amygdaloides</i> Anders.) -----	0.449	B. & B., 1, p. 495.
	Sandbar willow, river bank willow (<i>S.</i> <i>fluvialis</i> Nutt.) -----	0.497	B. & B., 1, p. 497.
	Glaucous willow, pussy willow (<i>S. discolor</i> Muhl.) -----	0.433	B. & B., 1, p. 499.
	Tulip wood:		
	Tulip tree (<i>Liriodendron tulipifera</i> Linn.) -	0.417	B. & B., 2, p. 49.
	Cucumber tree (<i>Magnolia acuminata</i> Linn.)	0.465	B. & B., 2, p. 48.
Fair (sp. gr., 0.45 to 0.60).	Red cedar (<i>Juniperus virginiana</i> Linn.) -----	0.493	Penhallow, p. 246.
	Hard pines:		
	Longleaf pine. (See under "Good.")		
	Bull pine (<i>Pinus ponderosa</i> Lawson) -----	0.471	Penhallow, p. 335.
	Loblolly pine (<i>P. taeda</i> Linn.) -----	0.544	Penhallow, p. 343.
	Pitch pine (<i>P. rigida</i> Mill.) -----	0.515	Penhallow, p. 319.
	Douglas spruce (<i>Pseudotsuga douglasii</i> Carr.) -----	0.516	Penhallow, p. 272.
	Cherry (<i>Prunus serotina</i> Ehrh.) -----	0.577	B. & B. 2, p. 253.
	Chestnut:		
	Chestnut (<i>Castanea dentata</i> (Marsh.) Borkh.) -----	0.449	B. & B. 1, p. 515.
	Chinquapin (<i>C. pumila</i> (Linn.) Mill.) ----	0.593	B. & B. 1, p. 515.

^a Britton, N. L., and Brown, A., Illustrated Flora of the Northern States and Canada, New York (1896-98).

TABLE VIII.—Approximate fuel value of North American woods—Continued.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Fair (sp. gr., 0.45 to 0.60).	Gum:		
	Sour gum, black gum (<i>Nyssa sylvatica</i> Marsh.) -----	0.642	B. & B. 2, p. 547.
	Gum (<i>N. aquatica</i> Linn.) (<i>N. uniflora</i> Wang.) -----	0.465	B. & B. 2, p. 547.
	Sweetgum (<i>Liquidambar styraciflua</i> Linn.) -----	0.594	B. & B. 2, p. 193.
	Holly (<i>Ilex opaca</i> Ait.) -----	0.577	B. & B. 2, p. 390.
	Mulberry (<i>Morus rubra</i> Linn.) -----	0.596	B. & B. 1, p. 528.
	Sassafras (<i>Sassafras variifolium</i> (Salisb.) Kuntze) (<i>S. sassafras</i> (Linn.) Karst.) -----	0.497	B. & B. 2, p. 97.
	Sycamore (button-ball tree) (<i>Platanus occidentalis</i> Linn.) -----	0.562	B. & B. 2, p. 194.
Good (sp. gr., 0.60 to 0.75).	Very hard pine:		
	Longleaf pine (<i>Pinus palustris</i> Miller) -----	0.700	Penhallow, p. 344.
	Larch or tamarack:		
	Tamarack (<i>Larix americana</i> Michx.) -----	0.624	Penhallow, p. 278.
	Tamarack (<i>L. occidentalis</i> Nutt.) -----	0.741	Penhallow, p. 277.
	Hackberry (<i>Celtis occidentalis</i> Linn.) -----	0.642	B. & B. 1, p. 526.
	Locust:		
	Black locust (<i>Robinia pseudacacia</i> Linn.) -----	0.738	B. & B. 2, p. 294.
	Honey locust (<i>Gleditsia triacanthos</i> Linn.) -----	0.673	B. & B. 2, p. 260.
	Maple:		
	Sugar maple (<i>Acer saccharum</i> Marsh.) -----	0.690	B. & B. 2, p. 398.
	Red maple (<i>A. rubrum</i> Linn.) -----	0.610	B. & B. 2, p. 397.
	Silver maple (<i>A. saccharinum</i> Linn.) -----	0.513	B. & B. 2, p. 397.
	Ash:		
	White ash (<i>Fraxinus americana</i> Linn.) -----	0.657	B. & B. 2, p. 601.
	Red ash (<i>F. pennsylvanica</i> Marsh. (<i>F. pubescens</i> Lam.) -----	0.626	B. & B. 2, p. 601.
	Black ash (<i>F. nigra</i> Marsh.) (<i>F. sambucifolia</i> Lam.) -----	0.626	B. & B. 2, p. 602.
	Blue ash (<i>F. quadrangulata</i> Michx.) -----	0.754	B. & B. 2, p. 602.
	Green ash (<i>F. lanceolata</i> Borck.) (<i>F. viridis</i> Michx.) -----	0.706	B. & B. 2, p. 601.
	Beech (<i>Fagus americana</i> Sweet) -----	0.690	B. & B. 1, p. 514.
	Birch:		
	Cherry, black, sweet birch (<i>Betula lenta</i> Linn.) -----	0.754	B. & B. 1, p. 510.
	Yellow birch (<i>B. lutea</i> Michx.) -----	0.657	B. & B. 1, p. 510.
	Red birch (<i>B. nigra</i> Linn.) -----	0.577	B. & B. 1, p. 509.
	Canoe birch (<i>B. papyrifera</i> Marsh.) -----	0.594	B. & B. 1, p. 509.
	Hornbeam:		
	Blue beech (<i>Carpinus caroliniana</i> Walt.) -----	0.722	B. & B. 1, p. 506.
	Coffee tree (<i>Gymnocladus dioica</i> (Linn.) Koch) (<i>G. canadensis</i> Lam.) -----	0.690	B. & B. 2, p. 261.
	Elm:		
	White elm (<i>Ulmus americana</i> Linn.) -----	0.650	B. & B. 1, p. 524.
	Rock elm (<i>U. racemosa</i> Thomas) -----	0.722	B. & B. 1, p. 524.
	Red elm (<i>U. fulva</i> Michx.) -----	0.690	B. & B. 1, p. 525.
	Winged elm (<i>U. alata</i> Michx.) -----	0.754	B. & B. 1, p. 525.

TABLE VIII.—Approximate fuel value of North American woods—Continued.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Good (sp. gr., 0.60 to 0.75).	Black walnut (<i>Juglans nigra</i> Linn.) -----	0.609	B. & B. 1, p. 483.
	Oak:		
	Red oak (<i>Quercus rubra</i> Linn.) -----	0.657	B. & B. 1, p. 516.
	Spanish oak (<i>Q. digitata</i> (Marsh.) Sudw.)		
	(<i>Q. falcata</i> Michx.) -----	0.690	B. & B. 1, p. 518.
	Pin oak (<i>Q. palustris</i> DuRoi) -----	0.690	B. & B. 1, p. 516.
	Black oak (<i>Q. velutina</i> Lam.) (<i>Q. tinctoria</i> Bartram) -----	0.706	B. & B. 1, p. 517.
	Water oak (<i>Q. nigra</i> Linn.) (<i>Q. aquatica</i> Walt.) -----	0.722	B. & B. 1, p. 519.
	Scarlet oak (<i>Q. coccinea</i> Wang.) -----	0.738	B. & B. 1, p. 517.
	Willow oak (<i>Q. phellos</i> Linn.) -----	0.738	B. & B. 1, p. 519.
	White oak (<i>Q. alba</i> Linn.) -----	0.738	B. & B. 1, p. 520.
	Bur oak (<i>Q. macrocarpa</i> Michx.) -----	0.738	B. & B. 1, p. 521.
Very good (sp. gr., 0.75 to 0.90).	Yellow oak (<i>Q. platanoides</i> (Lam.) Sudw.) (<i>Q. bicolor</i> Willd.) -----	0.770	B. & B. 1, p. 521.
	Basket oak (<i>Q. michauxii</i> Nutt.) -----	0.802	B. & B. 1, p. 522.
	Over-cup oak (<i>Q. lyrata</i> Walt.) -----	0.834	B. & B. 1, p. 521.
	Post oak (<i>Q. minor</i> (Marsh.) Sarg.) (<i>Q. obtusiloba</i> Michx.) -----	0.834	B. & B. 1, p. 520.
	Hickory:		
	Shagbark hickory (<i>Hicoria ovata</i> (Mill.) Britton) -----	0.834	B. & B. 1, p. 485.
	Mockernut hickory (<i>H. alba</i> (Linn.) Britton) -----	0.818	B. & B. 1, p. 486.
	Pignut hickory (<i>H. glabra</i> (Mill.) Britton) -----	0.818	B. & B. 1, p. 487.
	Bitter nut hickory (<i>H. minima</i> (Marsh.) Britton) -----	0.754	B. & B. 1, p. 485.
	Pecan hickory (<i>H. pecan</i> (Marsh.) Britton) -----	0.722	B. & B. 1, p. 484.
	Osage orange (<i>Maclura pomifera</i> (Raf.) Schneider) (<i>Toxylon pomiferum</i> Raf.) -----	0.770	B. & B. 1, p. 529.
	Persimmon (<i>Diospyros virginiana</i> Linn.) -----	0.786	B. & B. 2, p. 597.
	Eucalyptus (<i>Eucalyptus globulus</i> Labill.) -----	0.876	(*)

^a U. S. Dept. Agr., *For Ser.*, Cir. 179, 12. The average water content of the samples was 21.6 per cent.

TABLE IX.—Approximate fuel value of Philippine firewoods.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Poor (sp. gr., 0.25 to 0.45).	Rain tree (<i>Pithecolobium saman</i> Benth.) -----	0.417	Watt, ^a 61, p. 283.
Fair (sp. gr., 0.45 to 0.60).	Tambu Tambu (<i>Xylocarpus</i> sp.) -----	0.581	This paper, p. 12.
	Lumbayao (<i>Tarrietia javanica</i> Bl.) -----	0.546	This paper, p. 12.
	Bayub (<i>Pterospermum</i> sp.) -----	0.498	This paper, p. 12.

^a Dictionary of the Economic Products of India. Calcutta (1885-1896). No idea of the water content of the wood is given, but I presume that in most cases the wood was air dry.

TABLE IX.—Approximate fuel value of Philippine firewoods—Continued.

Fuel value.	Kind of wood.	Specific gravity.	Reference.
Good (sp. gr., 0.60 to 0.75).	Guava (<i>Psidium guajava</i> Linn.) -----	0.734	This paper, p. 12.
	do -----	0.673	Watt 6 ^I , p. 351.
	Camanchilis (<i>Pithecolobium dulce</i> Benth.) ----	0.610	Watt 6 ^I , p. 281.
	Tinduetinducan (<i>Aegiceras corniculatum</i> (Linn.) Blanco) (<i>Aegiceras majus</i> Gaertn.) -----	0.641	Watt 1, p. 116.
Very good (sp. gr., 0.75 to 0.90).	Agoho (<i>Casuarina equisetifolia</i> Forst.) -----	0.857	This paper, p. 12.
	do -----	0.834 to 0.882	} Watt, 2, p. 231.
	Tabigue (<i>Xylocarpus</i> sp.) -----	0.737	
	Tabigue (<i>Xylocarpus obovatus</i> A. Juss.) -----	0.722 to 0.802	} Watt, 2, p. 141.
	Pagatpat (<i>Sonneratia pagatpat</i> Blanco) -----	0.628	
	do -----	0.819	This paper, p. 12.
	do -----	0.845	This paper, p. 12.
	do -----	0.706	Watt, 6 ^{III} , p. 276.
	Lenggadi (<i>Bruguiera parviflora</i> W. & A.) ----	0.891	This paper, p. 12.
	Alabangbang (<i>Bauhinia malabarica</i> Roxb.) --	0.770	Watt, 1, p. 420.
Excellent (sp. gr., 0.90 or more).	Molave (<i>Vitex pubescens</i> Vahl) -----	0.882	Watt, 6 ^{IV} , p. 250.
	Pototan (<i>Bruguiera gymnorrhiza</i> Lam.) -----	0.756	This paper, p. 12.
	do -----	0.939	This paper, p. 12.
	do -----	0.866	Watt, 1, p. 541.
	Bacauan (<i>Rhizophora mucronata</i> Lam.) -----	0.983	This paper, p. 12.
	do -----	0.877	This paper, p. 12.
	do -----	0.994	This paper, p. 12.
	do -----	1.037	This paper, p. 12.
	do -----	1.130	Watt, 6 ^I , p. 491.
	Catutan (<i>Bruguiera</i> sp.) -----	0.901	This paper, p. 12.
	Tangal (<i>Ceriops tagal</i> (Perr.) C. B. Rob.) -----	0.885	This paper, p. 12.
	Tangal (<i>C. roxburghiana</i> Arn.) -----	0.738	Watt, 2, p. 261.
	Tangal (<i>C. tagal</i> (Perr.) C. B. Rob.) -----	1.008	Watt. ^b

^a See *Sonneratia apetala*.^b See *Ceriops candolleana*.

In the Philippines, as in other countries, almost all kinds of wood are used for fuel and charcoal. In the above table no attempt has been made to include any except those which are quite commonly used as firewood.

It may be said in general of woods otherwise equal, that those of low specific gravity kindle easily, flash up quickly and the fire spreads rapidly, while those of high specific gravity behave in the opposite way. There are other circumstances which can not accurately be anticipated by a chemical or physical examination. Some classes of wood burn with a still flame, others crackle, while still others easily deposit soot unless an abundant supply of air is present. Some woods of very high specific gravity are so crooked and inaccessible that they are often considered inferior to those of lower specific gravity which grow straight and are more easily available.

It is a familiar fact that many salts inclose small portions of water in their tiny crystals and when the crystal is heated it decrepitates on

account of the vaporization of this water. The crackling observed during the combustion of some woods may be explained on this basis. The popping of soft woods might be explained by the contained water being converted into steam whereupon the wood explodes, not being able to resist the strain. A large quantity of alkaline salts which are quite easily volatilized occur in the mangrove ash. Common salt (sodium chloride) melts at 820° . When mangrove woods are burned a large quantity of the ash is volatilized, which condensing on the walls of the furnace gradually builds up a clinker. Mangrove wood grown in the edge of the salt water was burned at the plant of a mining company in Masbate. It was found after a time that the furnace walls were clinkered badly. A specimen of this clinker, which is very saline, presented to me by Mr. Boag is shown in the following figure.



FIG. 1.—Furnace clinker formed when mangrove wood was burned.

The sample left on a cupboard shelf in my laboratory since September, 1907, over three years ago, shows crystals of sodium chloride due to efflorescence. The subject of volatile ash is worthy of special consideration, inasmuch as wood of this character used in the burning of pottery would materially influence the character of the glaze, or the glaze on crude pottery might be controlled by carefully selecting the firewood.

SUMMARY.

1. The chief woods used in the Philippines as fuel are the *Rhizophoraceæ*, although locally anything available is used. The consumption of firewood is at least 200,000 cubic meters annually.

2. Oven-dried wood will take up somewhat less moisture from the air than air-dried wood will retain of the original moisture of the green stick.

3. The best seasoned wood in this climate will retain moisture equal to 12.5 to 13 per cent of the weight of the dry wood. The dry weight is the only constant basis on which to compute the percentages of moisture and ash.

4. Some of the tables given are: (a) The determination of the calorific values of some Philippine woods; (b) The determination of the calorific values of some Philippine barks; (c) Analyses of wood ash; (d) The determination of the specific gravities of some Philippine woods; (e) The approximate fuel value of North American and Philippine firewoods.

5. The available heating value of the combustible matter of wood, wood—(water+ash), is practically constant and is equal to 4,418 calories. From this number the available heating value of a wood may be calculated when its moisture and ash content are known, as follows:

$$\text{Calories} = 4418 \times \left(\frac{100 - (\text{per cent water} + \text{per cent ash})}{100} \right) - 6 \times \text{per cent water}.$$

6. The three most important factors controlling the value of a wood for fuel are the content of moisture, the content of ash and the specific gravity.

7. The volatile constituents of a mangrove ash are large and may condense as clinker on the walls of a furnace or glaze the surface of anything with which they come in contact.

LIST OF ILLUSTRATIONS.

PLATE I.

- FIG. 1. Looking across a mangrove swamp at head of Tubugan Bay, Port Banga, Zamboanga. Yacal forest on hills in background.
2. *Sonneratia pagatpat* on the open coast. Old beach has been eroded, leaving a lagoon containing a mangrove swamp on the open coast. Bongabon, Mindoro.

PLATE II.

- FIG. 1. Interior view of a mangrove swamp. The large tree is *Sonneratia pagatpat* (pagatpat), those trees with prop roots are *Rhizophora conjugata* (bacao) and the smaller without prop roots are mainly *Bruguiera parviflora*. Bongabon, Mindoro.
2. Interior view of a mangrove swamp. The large tree is *Sonneratia pagatpat* (pagatpat), otherwise the stand is almost purely *Bruguiera parviflora*. Bongabon, Mindoro.

PLATE III.

- FIG. 1. Swamp along coast. Under water at high tide. Guinayangan, Tayabas.
2. Pagatpat "air roots." Trees growing in salt water.

PLATE IV.

- FIG. 1. Bacauan; root buttresses.
2. Bacauan; root buttresses.

PLATE V.

- FIG. 1. Pototan tree, along seacoast at low tide.
2. Pototan; lower trunk and roots.

PLATE VI.

- FIG. 1. Mangrove swamp at sitio Limbagujan. Stumps of tangal (*Ceriops*) in foreground. Trees of *Rhizophora* (bacauan) and *Bruguiera*.
2. Mangrove swamp. View of pieces of bacauan *rajas* (firewood).

PLATE VII.

- FIG. 1. Piled firewood cut mainly from sawed species of tangal and bacauan. Southwest coast of Camarines.
2. Cordwood. Baler, Nueva Vizcaya.

PLATE VIII.

- FIG. 1. Discharging *rajas* (firewood). Counting sticks by hand, two at a time.
2. Bundles of firewood at Quinta Market, Manila, sold at 20 centavos each Philippine currency.

PLATE IX.

- FIG. 1. Marketing firewood in Manila.
2. Firewood piled for sale in the Manila market.

PLATE X.

- FIG. 1. Lorchá load of *rajas* (firewood), three hours consumed in loading, two for discharging.
2. Firewood used for smoking fish.

TEXT FIGURE.

- FIG. 1. Furnace clinker formed when mangrove wood was burned.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.



FIG. 1.

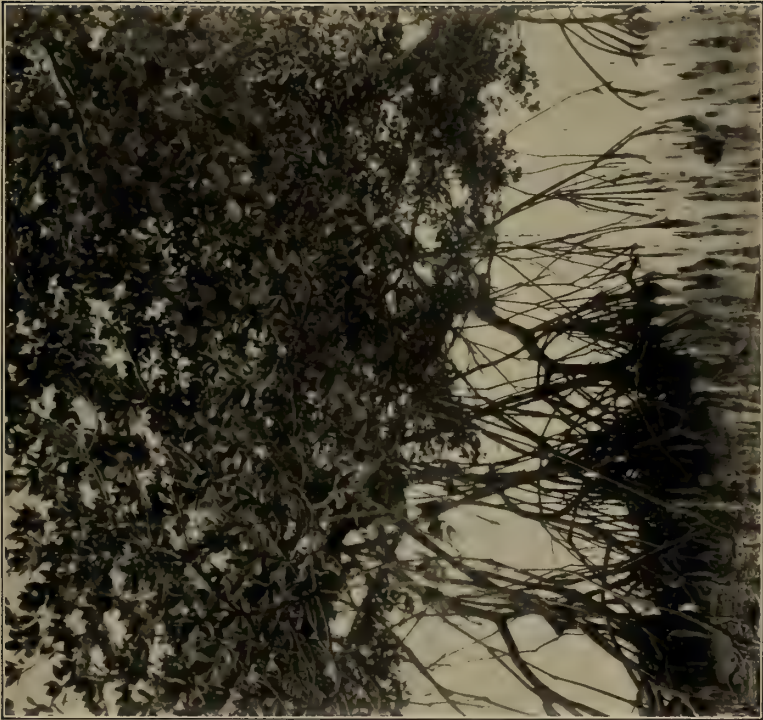


FIG. 2.

PLATE IV.



FIG. 1.



FIG. 2.



FIG. 1.

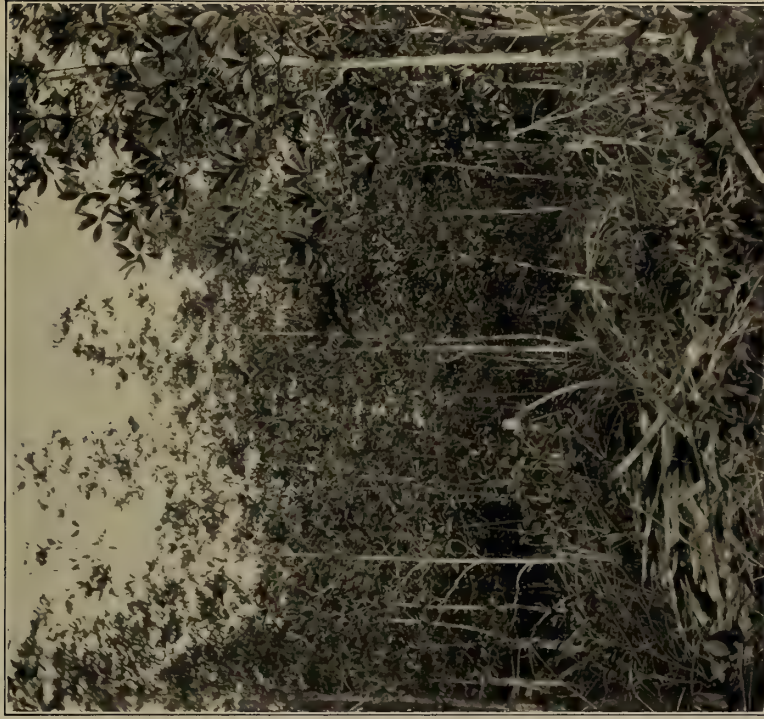


FIG. 2.

PLATE VI.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.

PLATE VIII.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.

QUININE ESTERS OF PHENYLARSINIC ACID DERIVATIVES.

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The results obtained in the treatment of surra with arsenophenylglycin by Strong and Teague, of the Biological Laboratory of this Bureau,¹ were so favorable that much hope was offered ultimately for a satisfactory cure of this infection. However, it was desirable that a less toxic preparation than arsenophenylglycin for the animal and one equally toxic for the parasite be secured. The following paper is the outcome of some work done in connection with Doctor Teague in the testing of the most promising drugs so far known for surra, which finally led to the chemical preparation of the quinine esters. After preparing several bodies which did not contain arsenic and after a discussion of the field of work with Doctors Freer and Strong, I took up the preparation of quinine derivatives and compounds which led finally to the preparation of a number of quinine esters of phenylarsinic acid derivatives.

The best drugs which have possibilities as a specific against surra known at the present time were found by Strong and Teague to be arsenophenylglycin and atoxyl. However, these are still far from being satisfactory, since the dose which is required to effect a cure is so close to the lethal one that too great a percentage of the animals treated with them succumb to arsenic poisoning.

Earlier investigators had paid pronounced attention to combinations of drugs. Amongst them the combined application of the derivatives of arsenic and salts of arsenious acid with alkaloids such as strychnine or quinine can be mentioned, but no better results were obtained from them.² These earlier experiments led to the plan of combining arsenic derivatives with alkaloids in such a way that the combinations would not be so easily split as would be the case with salts, such as, for instance, quinine arsenate which had found previous application. Thus, the combined action on the living cells of those two physiologically widely different substances is insured. Quinine itself has a pronounced action on trypanosomata, although this is considerably less than that of arsenic, and therefore my

¹ *This Journal*, Sec. B (1910), 5, 29.

² Uhlenhut, *Arb. a. d. kais. Gsndhtsmte.* (1909), 29, 403.

first attempt was to combine phenylarsinic acid derivatives with that alkaloid.

The molecule of quinine has necessarily to be altered as little as possible during the synthetic reaction, since it was shown by experiments on trypanosomata that slight changes in the structure diminish the desirable properties of the alkaloid. The following are the types of compounds the preparation of which was attempted:

1. Quinine combined in an ester with an aromatic derivative of arsenic acid; for instance, with benzarsinic acid, $\text{COOH} \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}_3\text{H}_2$, dibenzarsinic acid $(\text{COOH} \cdot \text{C}_6\text{H}_4)_2 \cdot \text{AsO}_2\text{H}$, phenylglycinarsinic acid $(\text{CO}_2\text{H} \cdot \text{CH}_2 \cdot \text{HN} \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}_3\text{H}_2)$, etc., to compounds corresponding to quininebenzoyl derivatives.

2. Quinine combined with oxy- or amidophenylarsinic acids by means of quinine-carbonic acid chloride, etc., to carbonates or urethane derivatives.

3. Direct combination of quinine with arsenic through direct substitution by means of arsenic trichloride.

4. A fourth type is produced by the combination of chitenin or a corresponding acid, with hydroxy- or amido-phenylarsenic derivatives. However, this type is under a disadvantage because the quinine enters into the compound in a form considerably less active in destroying trypanosomata than is the case with quinine.

I. BENZARSINIC ACID QUININE ESTER.

Benzarsinic acid was prepared from *p*-amidophenylarsinic acid by Sandmeyer's reaction.³

A number of experiments were carried out in chloroform and benzene for the purpose of combining the potassium salt of benzarsinic acid⁴ with quinine by means of phosphorus oxychloride as follows: $2\text{AsO}_3\text{H}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{CO}_2\text{K} + 2\text{C}_{20}\text{H}_{24}\text{N}_2\text{O}_2 + \text{POCl}_3 = \text{AsO}_3\text{H}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{CO}_2 \cdot \text{C}_{20}\text{H}_{23}\text{N}_2\text{O} + 2\text{KCl} + \text{KPO}_3$. This method seems preferable since it avoids the application of phosphorus pentachloride. The latter, when in excess, reacts on quinine, forming chlorquinine, and reacts on both acid groups of benzarsinic acid to produce the benzoyl chloride substitution product of arsenic pentachloride, $\text{AsCl}_4 \cdot \text{C}_6\text{H}_4 \cdot \text{COCl}$, and the group AsCl_4 would give the possibility of substituting hydrogen in quinine by chlorine.

The following reactions of this class were carried out with variations:

Phosphorus oxychloride was added in large excess to dry potassium benzarsinic acid, $\text{AsO}_3\text{H}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{CO}_2\text{K}$. A reaction sets in upon slight warming and hydrochloric acid is evolved. This proves that the reagent reacts not only with the salt, but at the same time with the free arsenic

³ A. Berskinn, *Ber. d. deutschen chem. Ges.* (1908), **41**, 1852.

⁴ La Coste, *Ann. d. Chem.* (Liebig) (1881), **208**, 6.

acid group. Phosphorus oxychloride readily combines with quinine. When the oxychloride is distilled *in vacuo* after the above reaction and a chloroform-quinine solution is then added and the whole warmed, reaction takes place very incompletely because of the insolubility of the different products, KPO_3 , HPO_3 , $\text{AsO}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{COCl}$ in chloroform, the half-liquid phosphorous acid protecting obstinately most of the acid chloride against quinine. The result was still more unsatisfactory when the salt was suspended in chloroform or benzene and the phosphorus oxychloride was then added.

Although the above method made it possible to isolate a product which doubtless contained both quinine and arsenic in combination, nevertheless it was abandoned for the following, by which benzoylchloride arsenic tetrachloride ($\text{COCl} \cdot \text{C}_6\text{H}_4 \cdot \text{AsCl}_4$) or benzoylchloride arsenic dichloride ($\text{COCl} \cdot \text{C}_6\text{H}_4 \cdot \text{AsCl}_2$) were obtained, and which gave satisfactory results by the final method described below.

Phosphorus pentachloride (4-gram molecules) were added to benzarsinic acid (1-gram molecule) dried at 120° and suspended in chloroform,



A spontaneous reaction took place, which was completed by boiling in a flask fitted with a reflux condenser until no more hydrochloric gas was given off and a clear solution resulted. Most of the phosphorus oxychloride was then removed by distilling the solution to dryness *in vacuo* on a water bath. The residue dissolves readily in chloroform and a chloroform solution of quinine (1-gram molecule) was then added. The precipitate which first formed again disappeared. After boiling for one-half hour the clear solution was distilled to dryness *in vacuo*. The residue consisted of the quinine ester-hydrochloride of carboxyphenyl-arsenic-tetrachloride, phosphorus oxychloride and a small quantity of chloroform. $\text{AsCl}_4 \cdot \text{C}_6\text{H}_4 \cdot \text{CO}_2 \cdot \text{C}_{20}\text{H}_{23}\text{N}_2\text{O}_2\text{HCl}$. The chloroform prevents the ready solution of the reaction product in water or hydrochloric acid even on heating; on the other hand, alkali saponifies it; and dissolving in alcohol, diluting with water and neutralizing with alkali gives a sticky precipitate of the quinine derivative. In view of these difficulties the best way was found to be the following:

On standing with cold water most of the phosphorus oxychloride decomposed; the solution was then heated on a water bath and by using a vacuum the chloroform was boiled off at a low temperature and solution thereupon readily took place. The resulting dilute solution was neutralized with sodium hydroxide until a precipitate began to form, and then precipitated by sodium carbonate solution. Excess of alkali is to be avoided, since the ester, stable as is its acid solution even on boiling with a considerable excess of acid, saponifies readily in presence of sodium hydroxide and slowly in sodium carbonate solution.

The free ester formed a dense precipitate; after standing for several hours it was filtered, washed and dried, first on a porous plate and subsequently at 110° . It still contained a certain amount of quinine, because the latter as a rule was used in slight excess over phosphorus pentachloride, but the quinine easily separated by dissolving the reaction product in a small quantity of absolute alcohol and precipitating with ether. The quinine dissolves, its benzarsinic ester forms a heavy white powder which is washed with ether and dried.

No free, uncombined benzarsinic acid can be present, because the ester was completely precipitated with sodium carbonate from its aqueous solution to a

slightly alkaline reaction; any uncombined acid would therefore remain in solution. A slight excess of benzarsinic acid over phosphorus pentachloride is necessary when beginning the reaction, because phosphorus pentachloride reacts with quinine, forming chlorquinine, which latter is precipitated, together with the ester, from the alcoholic solution by means of ether, and it requires a special operation to separate the two.

However, even if an excess of benzarsinic acid is present the products prepared according to this method always contained noticeable quantities of chlorine. No chlorine was found in the filtrate upon dissolving in dilute acid and reprecipitating; so that substitution in the organic portion of the molecule had taken place, probably because of the intermediate action of the tetrachlorarsinic portion of the original product of the reaction.

In view of the above difficulties another method was employed. Benzarsinic acid was first reduced to benzarsinious acid, so that no tetrachlorarsinic derivative would be produced while the acid chloride was being formed. After a number of experiments with different reducing agents such as SO_2 or SnCl_2 , and oxidizing agents for the subsequent oxidation, the following method was found to give satisfactory results.

Benzarsinic acid was suspended in chloroform and reduced to benzarsinic dichloride by means of phosphorus trichloride.⁵ Both the benzarsinic acid and the chloroform were dried carefully, since the presence of moisture caused the reduction in part at least to proceed farther than to the dichloride. If great care in this respect was not taken, a deep yellow product resulted, whereas it was colorless when the substances were previously dried.

La Coste believed it to be probable that the acid chloride of benzarsinic dichloride ($\text{AsCl}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{COCl}$) is formed, although analytical proofs, which would have required the difficult isolation of the compound, were not given. However, the product of the reaction does not combine with quinine when warmed with a chloroform solution of the latter, but does so only after it has reacted with phosphorus pentachloride, which proves that phosphorus trichloride has acted on the acid only sufficiently to form the dichlorarsenic derivative of the carboxylic acid $\text{COOH} \cdot \text{C}_6\text{H}_4 \cdot \text{AsCl}_2$. The same holds true if the reduction is not carried out in chloroform, but in the presence of phosphorus oxychloride or by means of pure phosphorus trichloride.

After the above reduction in chloroform suspension by means of phosphorus trichloride had taken place, the solution was evaporated to dryness *in vacuo* on a water bath, by which means the excess of phosphorus trichloride was removed. Chloroform was added to the residue and then phosphorus pentachloride (1-gram molecule). A spontaneous reaction set in, hydrochloric acid was developed and the residue went into solution. The whole was heated until the evolution of gas ceased and then cooled. A chloroform-quinine solution was thereupon added and the products again heated for one-half hour. The acid, aqueous solution of the reaction product, prepared in the same manner as was given for the benzarsinic acid ester, when neutralized gives a dense precipitate, which, differing from the arsenic-acid ester, does not dissolve in an excess of sodium carbonate or sodium hydroxide. It was filtered and washed, and since it still gave a strong reaction for chlorine when tested by heating with calcium oxide it was twice redissolved and reprecipitated. Chlorine was not removed in this way so that the body is the quinine ester of benzdichlorarsin: $\text{C}_{20}\text{H}_{23} \cdot \text{N}_2\text{O} \cdot \text{CO}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{AsCl}_2$. The chlo-

⁵ La Coste, *Ann. d. Chem. (Liebig)* (1881), 208, 16.

rine of course is easily removed by heating the body in dilute alcoholic alkali; for then the ester is saponified, the benzarsinic dichloride changing to benzarsinious acid and the hydrochloride of the alkali. The presence of benzarsinious acid in the solution of the chloride makes no difference; its silver salt, although insoluble in water, is readily soluble in dilute nitric acid. This affords another quick method for the chlorine determination.

Analysis.—Two and a half hours heating to 320° with nitric acid (specific gravity 1.5) was sufficient for complete decomposition; the filtrate from the chloride of silver was used for the determination of arsenic after the excess of silver nitrate had been removed.

I. 0.2351 gram substance gave 0.0617 gram $\text{Mg}_2\text{As}_2\text{O}_7$ and 0.0383 gram AgCl .

II. 0.2349 gram substance gave 0.0621 gram $\text{Mg}_2\text{As}_2\text{O}_7$ and 0.0368 gram AgCl .

Calculated for $\text{C}_{27}\text{H}_{27}\text{N}_2\text{O}_3\text{AsCl}_2$	Found per cent.	
Per cent.	I.	II.
As=13.1	12.4	12.7
Cl=12.2	11.4	11.8

When tested in the Biological Laboratory, in continuation of the research by Strong and Teague⁶ on chemotherapeutic specifics against surra, this compound showed an exceedingly high toxicity for trypanosomata *in vitro*. This is as would be expected, since in its chemical character it corresponds closely to *pamido*phenylarsinic oxide; but, on the other hand, it was equally toxic for the cells of the host, *in vivo*, and so the drug could not be used therapeutically in this connection.

It was therefore oxidized on the one hand to the arsinic acid and reduced on the other to the arseno-derivative. The chemical character of the arsenic in the former would correspond to that in atoxyl, in the latter to that in arsenophenylglycin.

A number of oxidizing agents were tried but without satisfactory result. Iodine, which has been used before in several cases,⁷ is excluded, since in every solvent that was used it combined with the alkaloid to form periodide before it reacted as an oxidizer. Red mercuric oxide, in several experiments with small quantities, gave rather satisfactory results when suspended in water and heated with the finely ground ester. However, as the primary product is so exceedingly toxic and there is no way of separating the unoxidized from the oxidized product without loss, it is important to oxidize completely. The usual analytical tests are not sufficiently sensitive to detect 1 to 2 per cent of unoxidized substance, so that the very convenient physiological test was employed. Ehrlich found in test tube experiments that a 1 per cent solution of *pamido*phenylarsinic acid has no action whatever on trypanosomata, whilst *pamido*phenylarsinious acid acts under identical conditions in dilutions up to 1 to 100,000. My arsinic dichloride derivative under the same conditions was found to act in a dilution of 1 to 20,000, but when it was completely oxidized its action corresponded only to the toxicity of its

⁶ *Loc. cit.*

⁷ Ehrlich and Berthenn, *Ber. d. deutschen chem. Ges.* (1910), 43, 917.

quinine constituent, namely to 1 to 800. A very small percentage of unoxidized product therefore markedly increases the toxicity.

However, mercuric oxide, because it is practically insoluble, reacts too irregularly with larger quantities of material; not only is the oxidation incomplete, but it also causes decomposition. Hydrogen peroxide was finally found to be most satisfactory as an oxidizer in hydrochloric acid solution. This reagent has been used before⁸ in slightly alkaline or acetic acid solution. A preliminary experiment proved that dilute hydrogen peroxide does not act upon quinine.

A few drops of the reagent was added to a solution of the alkaloid and the titanin test for hydrogen peroxide was then applied. Even after two days this very small quantity of hydrogen peroxide had not disappeared. When the reagent was added to the arsenic-quinine derivative, it was at once used for the oxidation, and the titanin test was positive only after the oxidation had become complete, as was proved by the test with living trypanosomata.

After the oxidation is complete, sodium hydroxide and carbonate precipitate a white, heavy, rather sticky substance, soluble in an excess of the alkali. A considerable quantity, in better form, precipitates on standing. The precipitate, filtered and washed, is dissolved in a very small amount of alcohol and reprecipitated by ether as a white, heavy powder, then filtered and dried with ether. It contains no chlorine: $C_{20}H_{23}N_2O \cdot CO_2 \cdot C_6H_4 \cdot AsCl_2 \longrightarrow C_{20}O_{23}N_2O \cdot CO_2 \cdot C_6H_4 \cdot AsO_3H_2$. The substance is readily soluble in acids, even acetic acid, and in alkali. It shows fluorescence in acid, but not in alkaline solutions.

II. THE DIQUININE ESTER OF DIBENZARSINIC ACID.

Di-pamidodiphenylarsinic acid was prepared by heating aniline arsenate with twice its weight of aniline to 185° in an oil bath at 200° for 1 to 2 hours. Mono-pamidodiphenylarsinic acid are formed in varying quantities. A smaller amount of a substance, which differs from di-pamidodiphenylarsinic acid in being much more soluble in 50 per cent acetic acid and crystallizing much slower, was also formed. It contains arsenic and has not been identified. The first two substances were separated by means of the differing solubilities of their sodium salts in alcohol,⁹ the second and third by repeated crystallization from 50 per cent acetic acid solution.

Twenty grams of the di-pamidodiphenylarsinic acid in 400 cubic centimeters hydrochloric acid were diazotized in the usual way with 9.4 grams of sodium nitrite, the solution was then added to a cuprous cyanide solution, prepared from 37 grams copper sulphate and 41 grams potassium cyanide. The clear, brown solution was filtered from the cuprous chloride, and, after being rendered

⁸ Michaelis, *Ann. d. Chem.* (Liebig) (1902), 320, 299; Ehrlich and Berthenn, *loc. cit.*

⁹ Benda, *Ber. d. deutschen chem. Ges.* (1908), 41, 1672.

alkaline and warming slightly, it was filtered from cuprous oxide. On boiling with a large excess of sodium hydroxide, ammonia is given off and the dinitrile saponified. After cooling, the solution is neutralized with hydrochloric acid; when acidified with acetic acid only part of the dibenzarsinic acid which is formed is precipitated, the remainder stays in solution as the acid salt and is decomposed only on heating with a large excess of acetic or with hydrochloric acid.¹⁰ Precipitation with acetic acid carries down the dark-colored impurities, leaving a slightly yellow solution; when treated with hot, concentrated hydrochloric acid, the impurities remain behind, and dibenzarsinic acid is formed; this is precipitated on cooling and dilution with water. It is a grayish powder, as is the precipitate from the original solution with hydrochloric acid. For analysis it was recrystallized from hot, concentrated hydrochloric acid.

I. 0.2164 gram substance gave 0.0946 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

II. 0.2349 gram substance gave 0.1012 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

Calculated for $\text{C}_{14}\text{H}_{11}\text{O}_6\text{As}$.	Found per cent.	
per cent.	I.	II.
As=21.4	21.1	20.7

Before treating the substance with phosphorus pentachloride, it was reduced for the reason given when benzarsinic acid was discussed. Two grams of the acid were dissolved in a solution of alkali and 5 grams of potassium iodide were added. Sulphur dioxide, passed through the warm solution and dilute sulphuric acid added to it, are successively employed. Dibenzarsinic acid liberates iodine from potassium iodide. After the reduction was complete, the acid was precipitated by the addition of more sulphuric acid. A white precipitate, resembling in everyway the original compound, appeared and was filtered off. The filtrate was then treated with hydrogen sulphide in order to prove whether arsenic had been split off, as in the case of other derivatives of arsenious acid, for instance, *pamidophenylarsenious oxide*.¹¹ A small quantity of a white precipitate, most probably the less soluble dibenzthioarsenious acid,¹² appeared, but not a trace of yellow arsenic trisulphide was visible.

However, the precipitate, after being thoroughly washed, gave a qualitative test for iodine, and even repeated solutions in alkali and precipitation did not remove the halogen. A certain amount of substitution by iodine seems therefore to have taken place, although no arsenic was split off. A second experiment with concentrated hydriodic acid and amorphous phosphorus gave the same result.

As a result, instead of first reducing the acid it was treated directly with phosphoruspentachloride.

Five grams of dry dip-benzarsinic acid were added to 25 grams phosphorus oxychloride. The body dissolved without visible reaction. After heating it slightly, 6 grams of phosphorus pentachloride were added. The development of hydrochloric acid began at once and was completed by heating the solution to 90° to 100°. The greater part of the solution which contained dibenzoylchloride arsinic trichloride $(\text{ClCO} \cdot \text{C}_6\text{H}_4 \cdot)_2\text{AsCl}_3$, etc., was then distilled *in vacuo* and chloroform added; phosphoric acid precipitated, the acid chloride remained in solution. Eleven grams of quinine (required 9.3 grams) in chloroform were then added, and the mixture boiled on a reflux condenser for one hour, after which most of the chloroform was distilled off. The thick, light brownish residue was thoroughly worked through with ice water in order to decompose chlorphos-

¹⁰ La Coste, *Ann. d. Chem. (Liebig)* (1881), **208**, 22.

¹¹ Ehrlich and Bertheim, *Ber. d. deutschen chem. Ges.* (1907), **40**, 2292.

¹² La Coste, *loc. cit.*

phorus compounds¹³ and then warmed on a water bath. As the chloroform distilled off, the solid passed into solution, with the exception of a very slight residue in a relatively small quantity of water. Since dibenzarsinic acid is insoluble under such conditions, and is soluble in dilute acid only as its quinine ester, it was completely esterified.

Sodium carbonate produced a very fine precipitate from this solution, insoluble in an excess of the reagent and differing widely from quinine in its appearance. No precipitate of dibenzarsinic acid was noticed on acidifying the filtrate. The white residue was washed and dried at 130°. This treatment rendered it slightly yellow, but it was still completely and very easily soluble in dilute hydrochloric acid. The ester still contained some free quinine, as the alkaloid was used in excess. To remove the latter it was dissolved in a small quantity of absolute alcohol and precipitated by ether. The benzarsinic acid derivative precipitates, and quinine remains in solution. Di-quinine dibenzarsinic acid is a fine, white powder, which is filtered and washed dry with ether. The yield was 8 grams.

I. 0.2614 gram substance gave 0.0408 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

II. 0.2802 gram substance gave 0.0443 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

Calculated for		Found per cent.	
$\text{C}_{54}\text{H}_{55}\text{N}_4\text{O}_8\text{As}$		I.	II.
$(\text{C}_6\text{H}_4\text{CO})_2 : (\text{C}_{20}\text{H}_{23}\text{N}_2\text{O}_2)_2 : \text{AsO}_2\text{H}$			
Per cent.			
As=7.8		7.4	7.6

III. ACETYLPHENYLGLYCIN-ARSINIC ACID QUININE ESTER.

Besides the two esters already described, I endeavored to prepare the quinine ester of phenylglycin-arsinic acid, with the intention of reducing it to the di-quinine ester of arsenophenylglycin, because the latter drug has proved so far to be the most successful specific for surra.

Phenylglycin-arsinic acid was prepared by boiling the sodium salt of pamidophenylarsinic acid¹⁴ (1 gram molecule) with monochloroacetic acid (2 gram molecules) in aqueous solution for five hours on a reflux condenser. The addition of sodium carbonate (0.5 gram molecule) did not noticeably improve the yield. Hydrochloric acid (1 gram molecule) was then added to keep any unchanged acid in solution. Although phenylglycinarsinic acid is only slightly soluble in water or dilute hydrochloric acid, it sometimes persists obstinately in remaining in solution and can then only be precipitated on cooling with ice and scratching with a glass rod. Unchanged acid was reprecipitated from the filtrate and used for further preparation. The residue, crystallized once more from dilute hydrochloric acid, was pure and free from pamidophenylarsinic acid:

I. 0.3248 gram substance gave 0.1812 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

II. 0.2879 gram substance gave 0.1586 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

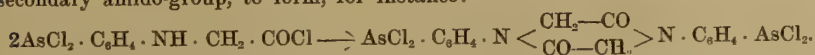
Calculated for $\text{C}_8\text{H}_{10}\text{NO}_5\text{As}$		Found per cent.	
$\text{CO}_2\text{H} \cdot \text{CH}_2 \cdot \text{HN} \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}_3\text{H}_2$		I.	II.
Per cent.			
As=27.2		26.9	26.5

It would be reasonable to expect that the carboxychloride could be obtained by the action of phosphorus trichloride on the free acid, but, on the other hand, it might also be possible that the acid chloride itself, especially during its

¹³ When a small quantity is treated at once with warm water, a considerable quantity decomposes to its constituents.

¹⁴ *Chem. Centralbl.* (1909), I, 234 (pat.).

formation, would react in an intermolecular or intramolecular manner on the secondary amido-group, to form, for instance:



Phosphorus trichloride of course will not only react upon the carboxyl group, but at the same time reduce the acid and form the benzarsinic dichloride derivative.

Therefore different methods were used in the attempt to obtain a compound which on decomposition with water and alkali would give a substance with the properties to be expected of the reduction product of phenylglycinarsinic acid, namely, phenylglycinarsinious acid.

Dry phenylglycinarsinic acid, added to phosphorus trichloride or phosphorus oxychloride, reacts almost immediately and is charred or largely changed into compounds which are yellow or insoluble in ammonia. A slight reaction takes place in the cold if the acid is suspended in chloroform and phosphorus oxychloride added. After this addition, cold phosphorus trichloride-chloroform solution was added, and the reaction started by gentle heating, much hydrochloric acid being given off. A considerable rise in temperature takes place on adding a chloroform solution of quinine, but on isolating the products, the arsenic derivative and quinine were found to be uncombined. When, on the other hand, phosphorus trichloride and oxychloride are for the greater part distilled off *in vacuo*, decomposition takes place resulting in compounds which are insoluble in ammonia. Phenylglycin itself, or nearly related derivatives like methylphenylglycin, are known to be rather unstable in as far as they easily give off carbon dioxide, and it is therefore not surprising to find a compound like $\text{AsCl}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{NH} \cdot \text{CH}_2 \cdot \text{COCl}$ also to be unstable. Without investigating whether this compound existed or not, it was set aside as not being suited for the preparation of larger quantities of the quinine ester.

Instead, I attempted to prepare the ester of its acetyl derivative, this change in any event excluding the action of the carboxychloride group on the secondary amido group.

When the carefully dried phenylglycinarsinic acid (10 grams) was added to cold acetylchloride (35 grams), a slow reaction set in which was completed by slightly warming on a reflux condenser. The solution had become dark red, and only part of the substance had gone in solution. After the reaction had ceased, the solution was allowed to stand for one hour and was then evaporated under diminished pressure by means of a dry current of air. On addition of ice water and gradual and careful addition of sodium hydroxide, avoiding an excess, the reaction product easily and completely dissolved to a brown solution. This was acidified with acetic acid which at once gave a yellow precipitate; after standing one hour, addition of acetic acid had no further effect. The precipitate was then filtered (3.5 grams), hydrochloric acid afterwards at once precipitated the remainder of the substance as an almost white compounds (6.5 grams). The instantaneous precipitation, and the form of the crystals, which differs widely from that of the leaf-shaped ones of phenylglycinarsinic acid, were a first indication that the substance was not the original acid. Its sodium salt is decomposed by acetic acid, whereas the sodium salt of phenylglycinarsinic acid is not. The compound is an acid and it was found to contain arsenic. Since acetylphenyl sodium arsenate is not decomposed by acetic acid, this first compound mentioned above and separated by acetic acid, is very probably an intermolecular amide, perhaps: $\text{AsO}_3\text{H}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{N} \begin{array}{c} \text{CH}_2-\text{CO} \\ \text{CO}-\text{CH}_2 \end{array} \text{N} \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}_3\text{H}_2$, formed

because of the tendency sometimes shown by acetylchloride to dehydrate instead of acetylate. It will be identified at a subsequent time.

The second compound which was precipitated instantaneously by hydrochloric acid was found to be the compound desired. The solution of its sodium salt which, however, has still a slightly acid reaction, was warmed to about 45° in the presence of animal charcoal, to remove the brownish tinge.

Acetylphenylglycinarsinic acid, as expected, proved to be insoluble in concentrated hydrochloric acid, this fact affording a separation from the original acid. It regenerated the latter very readily on warming or even standing with an excess of ammonia, etc.; when dissolved in insufficient alkali to cause an alkaline reaction of the solution, hydrochloric acid again instantly produced a precipitate, whereas if it is allowed to stand in a warm solution of alkaline reaction, hydrochloric acid produces no immediate precipitate, as phenylglycinarsinic acid, although only slightly soluble in water, precipitates with difficulty.

Four grams (1 gram molecule) of acetylphenylglycin arsinic acid, dried for some days in a desiccator over calcium chloride and then at 110°, ¹⁵ were suspended in dry chloroform, 6 grams of phosphorus oxychloride added and the whole slightly warmed until a change in the consistency of the suspended compound indicated a reaction between the two substances. Seven and two-tenths grams (3 gram molecules), (of which two were assumed to react upon the arsino group $R AsO_2$) of phosphorus pentachloride, in chloroform solution, were then slowly added to the cold suspension. A clear solution resulted, the temperature being kept between 30° to 35°. The flask, kept in a water bath of this temperature, is for a short time then connected with the vacuum, whereupon a gas, largely if not wholly consisting of hydrochloric acid, is given off. Six grams of quinine in chloroform were then added to the cold, clear solution, no precipitate being formed. Chloroform and phosphorus oxychloride were then distilled off *in vacuo* at 30°, and the residue worked through thoroughly with ice water. The solid substance went into solution with but a very small residue, after the flask, in a water bath at 25°, was connected with the vacuum and shaken. The brownish solution was precipitated in fractions in order to avoid excess of the alkali, the white, voluminous precipitate dried on a porous plate, in a desiccator, dissolved in a very small quantity of absolute alcohol, precipitated with ether as a heavy white powder, filtered and washed dry with ether (4.5 grams). Eight grams of the ester are in reality formed, but aside from other losses, it is not inconsiderably soluble in ether containing alcohol. The compound was dried in a desiccator and then at 100° without apparent change.

It dissolves at once in dilute hydrochloric acid and the solution remains clear even if the reaction is strongly acid; it only dissolves with difficulty in acetic acid, most easily in dilute ammonia, easily in dilute sodium hydroxide and sodium carbonate. The solution in ammonia, especially if only the required quantity of ammonia is used, remains clear for several hours and then begins slowly to become murky, whereas the two other alkaline solutions, or a solution formed by a trace of sodium hydroxide added to the ammonia solution, quickly form a voluminous

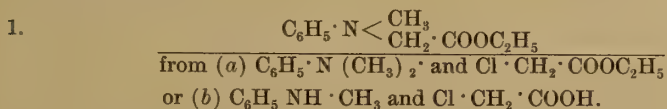
¹⁵ The compound decomposes at 130° without melting.

precipitate of quinine. The solubility in organic solvents corresponds exactly with that of the other arylarsinic acid quinine esters. In order to prove whether any reduction of the arsinic group had taken place 0.5 gram of the compound was dissolved in 5 cubic centimeters of dilute hydrochloric acid; the titanin acid test was negative, but became positive and remained so on the addition of two drops of a 2 per cent hydrogen-peroxide solution.¹⁶

Amongst the other drugs which were tested the following may be mentioned:

1. An extract of the stem of *Tinospora reticulata* Miers, *macabuhay*.¹⁷ Although the plant has an exceedingly bitter taste and is used for various medicinal purposes, neither Bacon nor others who worked with it have been able to find any physiologically active substances. There were 170 grams at my disposition; a few tests with the material proved that whilst the sap of a fresh cut is exceedingly bitter, the latter taste disappears entirely in ten to twenty minutes when a relatively thin slice is exposed to the air. This change is due to a rapid oxidation which the very unstable bitter substance undergoes, since a test proved that it does not take place, or at least takes place much more slowly in an atmosphere of carbon dioxide. This fact is not mentioned in the former note¹⁸ on *macabuhay*, and it may have been overlooked during the preparation of the extracts. "If drying did not effect the bitter taste," it probably was done in a specific way, instead of crushing the material and boiling it with water. In my work the stems were cut in slices under water, both were filled in a bottle up to the neck and warmed for several hours on the water bath. The solution was then filtered and evaporated in an atmosphere of carbon dioxide with a reduced pressure of 30 millimeters. A few drops of the solution added to dilute mercury potassium-

¹⁶ Since the yield of this ester, calculated upon the weight of pamidophenylarsinic acid, is so poor and the materials so expensive, the following method (*Ber. d. deutschen chem. Ges.* (1884), 17, 2661), for preparing a corresponding ester is under way:



2. It is expected that $\text{C}_6\text{H}_5 \cdot \text{N} < \begin{smallmatrix} \text{CH}_3 \\ \text{CH}_2 \end{smallmatrix} \cdot \text{COOC}_2\text{H}_5$ will react with arsenic chloride, as dimethyl and diethyl amidobenzol very easily do without heating and with a good yield, forming $\text{AsCl}_2 \cdot \text{C}_6\text{H}_4 \cdot \text{N} < \begin{smallmatrix} \text{CH}_3 \\ \text{CH}_2 \end{smallmatrix} \cdot \text{COOC}_2\text{H}_5$. This ester can be saponified, and then esterified with quinine.

Preliminary experiments showed that the first intermediate product, methylphenylglycin ethylester is formed in very good yield when the two compounds are heated in a xylol bath to 136° for eight to nine hours; no carbon dioxide whatever is given off at this temperature.

0.2685 gram substance gave 0.0634 gram $\text{Mg}_2\text{As}_2\text{O}_7$.

Calculated for $\text{C}_{20}\text{H}_{23}\text{N}_2\text{O}_2 \cdot \text{CO}_2 \cdot \text{CH}_2 \cdot \text{HN} \cdot \text{C}_6\text{H}_4 \cdot \text{AsO}_3\text{H}_2$ Per cent.	Found per cent.
As=12.00	11.4

¹⁷ Bacon, *This Journal* (1906), 1, 1030.

¹⁸ *Ibid.*

iodide or tungstic acid solution gave no precipitation; no alkaloid was therefore present. The bitter taste was intense, but 5 to 10 cubic centimeters injected subcutaneously into a guinea pig infected with surra did not result in the disappearance of the trypanosomata. No further physiologic tests were made.

COMPOUNDS TESTED FOR ACTION ON TRYPANOSOMATA.

<i>Tinospora reticulata</i> Miers extract (<i>macabuhay</i>)	Hydrazine.
Phenylhydrazine hydrochloride, dissolved and the free base suspended in water.	Hydroxylamine.
Formylphenylhydrazine ($\alpha\alpha$ methyl- β formylphenylhydrazine)	Semicarbazid.
$\alpha\alpha$ Methylphenylhydrazine	Pikrotoxin.
Ethylmercaptane	Curare.
(Potassium cyanide)	Nicotine.
Tin tartrate	Coniin.
Potassium iodide	Berberine.
Azimidol	Chinotoxin.
Dimethylamidophenyldichlorarsin	Quinine.
Benzarsinious chloride quinine ester	Quinine peroxide.
Arsenobenzoic acid quinine ester	Cinchotinin, cinchotin ethyl ether.
Benzarsinic acid quinine ester	Apoquinine (tartrate, oxalate, nitrate).
Dibenzarsinic acid diquinine ester	Oxalic acid.
Acetylphenylglycinarsinic acid quinine ester	

THE MECHANICAL ANALYSIS OF SOIL.

By WALLACE E. PRATT.

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A soil survey of the sugar lands of the Island of Negros, Philippine Islands, has been made by Mr. Herbert S. Walker,¹ formerly of the Chemical Laboratory of this Bureau, necessitating a large number of mechanical soil analyses. Some modifications of the usual methods have been devised and are given in this paper, together with a few analytical results.

Mechanical analysis consists of separating the "fine earth" portion of soil into its individual grains or particles, and of placing these grains, according to their size, in groups the limits of which are established arbitrarily, with a view to ease of separation and the importance of the grain size of each to the general soil character. The Bureau of Soils of the United States Department of Agriculture have carefully outlined the general method as practical by them.² They divide the soil into seven groups, as follows:

Group No.	Separated by—	Conventional name.	Diameter of grains.
			mm.
1	Screen	Fine gravel	2.0 -1.0
2	do	Coarse sand	1.0 -0.5
3	do	Medium sand	0.5 -0.25
4	do	Fine sand	0.25-0.10
5	do	Very fine sand	0.10-0.05
6	Sedimentation	Silt	0.05-0.005
7	Centrifuge	Clay	<0.005

Nothing above 2 millimeters in diameter enters into the analysis, because usually the same sample is employed for the mechanical as well as for the chemical analysis. The samples for the mechanical analyses

¹ The Sugar Industry in the Island of Negros, Bureau of Science, Manila, 1910, Pub. P. I. Bur. Science (1910) Bulletin.

² Bull. U. S. Dept. Agric., Bur. Soils (1904), No. 24.

given in this paper had been passed through a 1-millimeter screen and therefore group number 1 was calculated into the analysis from the figures for detritus on a 1-millimeter screen; therefore, it includes all material above 1.0 millimeter in diameter. There is only a negligible difference between this and the "fine gravel" group of the analyses of the Bureau of Soils; in fact, in a number of our analyses the group is absent entirely and it is probable that in the others all of this group would have passed a 2-millimeter screen.

Other slight variations from those specified in Bulletin No. 24 of the Bureau of Soils were used and are of sufficient interest to justify discussion. Our shaker is an ordinary laboratory machine run at 90 throws per minute instead of 100 and for this reason the shaking was continued slightly longer. In the centrifuge modeled after that described in Bulletin No. 24 we use brass tubes turned to a smooth surface inside instead of glass. Brass tubes are not subject to the occasional breakage that occurs with the test tubes, even though the latter are well annealed. They are quite as easily cleaned, but are open to the objection that they are not transparent.

The time or rotation of the centrifuge necessary to settle a particle of a given diameter depends on the speed of rotation and the distance of the end of the centrifugal tube from the shaft axis. Our centrifuge rotates at 700 revolutions per minute at full speed and the distance of the end of the centrifugal tube from the shaft axis is 22 centimeters. The centrifuge is operated until an examination with a microscope shows no particles above a certain average size and shape in suspension. Freak grains or scales must be ignored and the average largest grain taken. Three minutes is the average time required for the separation of all but the clay group. Time is counted from the time full speed is attained, fifteen seconds after the current is turned on. Once determined, the time of centrifugating varies from a constant only as the specific gravities of the particles of a given size vary, which is little. Occasionally, especially for the first period of rotation of a sample of heavy clay, a little additional time is necessary.

This is quite natural since much more clay is in suspension at first than will be present after the first decantation has been made. When much clay is in suspension it is probable a condition exists approaching that which Richards³ terms a "hindered settling condition," i. e., a grain which tends to settle may be interfered with and held up by its floating companions. In subsequent rotations, when most of the clay is gone, such a grain settles unobstructedly.

About thirty seconds of rotation in the centrifuge is necessary for the

³ Ore Dressing. New York, 2 ed. (1908), 1, 464.

separation of all the particles greater than 0.05 millimeter in diameter, i. e., all but the silt. This separation is about twice as fast as that calculated on the basis of a specific gravity of 2.6 by one of the numerous formulas for the velocity of bodies falling free in water. Only a part of this difference can even be accounted for by a deviation in the specific gravity. We believe the greatest variable is the additional time required for the careful decantation of the silt and the possibility of grains getting out of suspension by settling against the side of the tube when inclined in pouring.

The Bureau of Soils specifies brass screens with round perforations for the separation of groups numbers 1 and 2 and silk bolting cloth of proper mesh for the separation of groups numbers 3 and 4. The bolting cloth of course has a square mesh. We used a nest of square-mesh brass screens throughout. A series of measurements along the central wire in each direction was recorded as follows:

Size of screen (meshes to the inch).	Mesh dimensions.		Mesh desired.
	Largest.	Average.	
	<i>mm.</i>	<i>mm.</i>	<i>mm.</i>
30	0.57	0.54	0.50
60	0.28	0.22	0.25
150	0.01	0.08	0.10

We believe the square-mesh wire screens preferable to the bolting cloth in that they are more readily and perfectly cleaned. Since the meshes for the two smaller grained sands are of necessity square, the advantage gained in having those for two larger grained sands round is for the greater part lost.

With care the various grains may be sized satisfactorily. With a sample of 5 grams an error of 10 milligrams amounts to only 0.2 per cent, yet this perfection of manipulation can be obtained if glazed paper is used, wedged grains are removed from the sieves and all operations are carefully performed. In all this work much can be accomplished by systematizing the operations. Repeated drying to constant weight may also be avoided. Experiments with both samples and different separations show that a period of three hours at a temperature of 100° to 112° is sufficient thoroughly to dry either. Two hours usually suffices to dry the separated sands.

The Bureau of Soils ⁴ has published the following table of eight analyses of 5-gram samples of the same soil with the statement that it "may

⁴ *Loc. cit.*

fairly be taken to represent the limit of accuracy attainable by the centrifugal method under the most favorable conditions" as follows:

Soil.	Diameter of grains.	Sample No. 5862—							
		(a).	(b).	(c).	(d).	(e).	(f).	(g).	(h).
	mm.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Loss on ignition -----		12.5	12.2	10.9	12.2	12.0	12.2	12.4	11.9
Fine gravel -----	2.0 -1.0	2.6	2.6	2.6	2.4	2.4	2.3	2.8	3.2
Coarse sand -----	1.0 -0.5	5.3	5.1	5.1	5.1	5.3	5.6	5.6	5.2
Medium sand -----	0.5 -0.25	4.2	4.8	4.6	4.5	4.4	4.5	4.9	4.4
Fine sand -----	0.25-0.10	13.0	13.2	14.2	13.8	14.4	12.8	13.6	12.6
Very fine sand -----	0.10-0.05	7.7	7.3	8.8	7.2	7.8	8.0	8.4	7.3
Silt -----	0.05-0.005	16.8	17.6	15.8	16.7	16.0	16.4	15.1	17.2
Clay -----	0.005 and less.	38.3	37.5	38.1	37.9	38.0	38.0	37.6	37.7

The following table shows duplicate analyses of 5-gram samples of the same soil run in the same set in the chemical laboratory of this Bureau.

Soil.	Diameter of grains.	Sample No.—					
		71 A.	71 A.	73 A.	73 A.	87.	87.
	mm.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Fine gravel -----	2.0 -1.0	0.2	0.2	9.7	9.7	2.6	2.6
Coarse sand -----	1.0 -0.5	0.2	0.2	1.7	1.6	1.1	1.3
Medium sand -----	0.5 -0.25	2.5	0.6	9.2	9.0	3.5	3.6
Fine sand -----	0.25-0.10	15.5	16.1	10.6	11.7	8.4	7.4
Very fine sand -----	0.10-0.05	23.7	23.0	11.2	11.8	12.7	12.8
Silt -----	0.05-0.005	43.4	43.4	35.6	35.5	34.7	34.5
Clay -----	0.005 and less.						
Total -----		99.8	100.3	100.6	100.6	100.1	100.4

The following table shows duplicate analyses of 5-gram samples of several soils, run in different sets:

Soil.	Diameter of grains.	Sample No.—							
		6.	6.	6.	7.	7.	7.	8.	8.
	mm.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Fine gravel -----	2.0 -1.0	4.3	4.3	4.3	8.2	8.2	8.2	1.9	1.9
Coarse sand -----	1.0 -0.5	3.4	3.4	3.0	1.7	2.0	2.0	1.3	1.3
Medium sand -----	0.5 -0.25	10.6	11.2	11.3	10.4	11.1	10.5	6.1	5.7
Fine sand -----	0.25-0.10	11.5	11.7	12.1	12.8	13.8	12.7	9.3	9.0
Very fine sand -----	0.10-0.05	14.3	14.5	13.8	12.7	12.1	12.0	12.7	13.0
Silt -----	0.05-0.005	37.6	35.7	35.7	33.5	31.8	31.4	41.4	45.9
Clay -----	0.005 and less.	18.4	18.9	19.8	20.5	22.1	21.9	26.7	25.1
Total -----		99.7	100.0	100.1	100.0	100.0	99.8	99.7	99.9

It will be seen that none of the foregoing analyses shows more variation than those of the Bureau of Soils.

Hilgard⁵ has proposed as a graphic representation of the mechanical structure of soils as determined by analysis, that photographs be published showing glass tubes containing the separations arranged in order of grain size on the assumption that the depth of material in each vial is proportional to the amount of the sized material in the soil and that the surfaces in the row of tubes describe a curve of the soil composition. An objection to this scheme is that the clay and silt cake in drying and fill their tubes largely with void space. The sands also have different percentages of voids, varying with the sizes of the grains, so that representation made by photograph is not accurate.

A more accurate, complete and satisfactory way of showing the soil character is that made apparent in the accompanying text figure, which represents graphically the mechanical composition by weight of a surface soil and its subsoil. Not only the relative proportion of the different grain sizes is shown, but also the physical composition of the soil as a whole.⁶ By means of such curves the relation of a soil to its subsoil is at once apparent and comparisons may readily be made with other soils. The prospect of a crop may partially be interpreted by comparing with the curve for the ideal soil for that crop.

Often, a knowledge of the geologic features of a region will aid in advance interpretation of soil character and taken together with the physical analysis the two supplement each other. The reverse is also true that one can often interpret certain geologic features from the soil analysis, as shown by the following analyses of Philippine soils.

Table of analyses of Philippine soils.

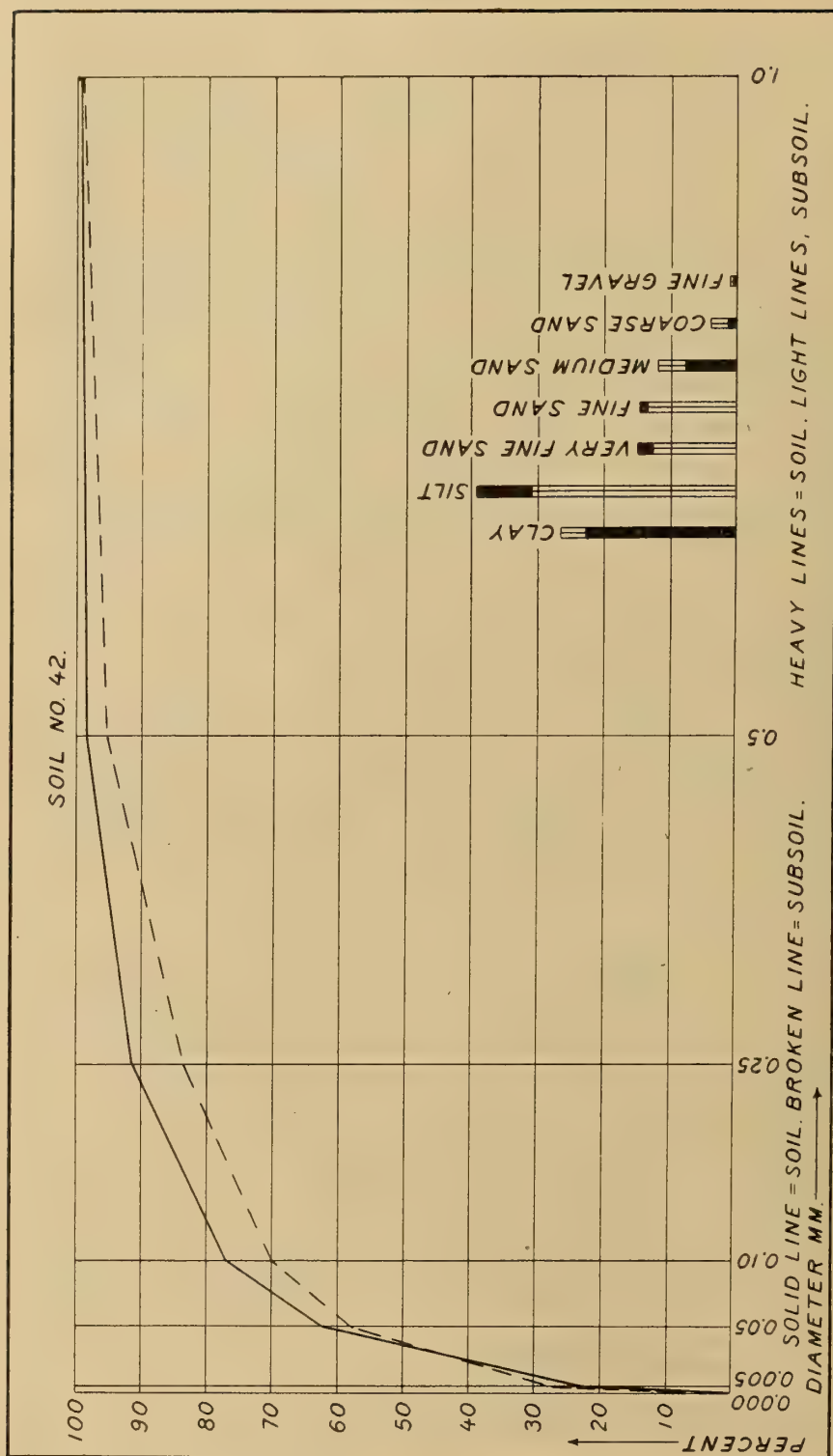
Soil.	Diameter of grains.	Sample No.—							
		1 ^a .	1 ^b .	2 ^a .	2 ^b .	3 ^a .	3 ^b .	4 ^a .	4 ^b .
	mm.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
Fine gravel-----	2.0 -1.0	12.3	41.8	0.0	0.1	14.2	20.1	0.8	0.8
Coarse sand-----	1.0 -0.5	6.6	6.7	0.1	0.0	1.4	1.0	5.9	3.9
Medium sand-----	0.5 -0.25	13.7	15.1	1.0	0.4	5.0	3.5	30.1	26.3
Fine sand-----	0.25-0.10	12.8	10.5	12.2	13.7	7.8	7.3	26.4	26.1
Very fine sand----	0.10-0.05	12.2	6.0	15.4	12.8	12.9	13.4	11.6	10.4
Silt-----	0.05-0.005	30.0	13.4	52.0	51.7	40.0	40.5	12.2	15.1
Clay-----	0.005 and less.	12.7	5.5	19.2	20.4	18.7	14.4	13.2	17.4
Total -----		100.3	100.0	99.9	99.1	100.0	100.2	100.2	100.0

^a Surface soil.

^b Subsoil.

⁵ Soils, New York (1907), 94.

⁶ This would only be approximated by a photograph of the tubes.



A GRAPHIC REPRESENTATION OF THE PHYSICAL COMPOSITION OF SOILS.

The relationship of the surface soil to subsoil in number 1 suggests a residual decomposition. In soil number 2, the surface and subsoil are quite similar, suggesting an alluvial deposit. Number 3 shows a large amount of silt which is apparently tuffaceous and number 4 is largely marine sand.

More than a suggestion of the relation that exists between the geology of an area and the data of the mechanical analyses of its soils is not possible unless the geologic data are complete.

ILLUSTRATION.

TEXT FIGURE.

Text figure showing graphically the physical composition of soils.

THE ECONOMIC POSSIBILITIES OF THE MANGROVE SWAMPS OF THE PHILIPPINES.¹

By ROBERT R. WILLIAMS.

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Tanning materials are being imported into the United States in such rapidly increasing amounts that the importations now form a large percentage of the total quantity consumed. In ² 1900 the assessed value of such imports was about 1,600,000 dollars which in 1910 had grown to a sum exceeding 6,500,000 dollars. The increase has largely been due to the economical manufacture of extracts and to the development of quick tanning processes which demand materials of high concentration. In 1909, the last year for which reliable figures are available,³ 10,779,177 dollars were paid for tanning extracts, while the total amount expended by American tanners for vegetable tanning materials was 21,904,927 dollars. By far the most important extracts are South American quebracho and domestic chestnut. The cost of the former in 1909 was 5,877,989 dollars, and of the latter, 3,579,929 dollars. Hemlock, palmetto, and gambier, supplemented in recent years by myrobalans and mangrove, constitute the remainder of extracts used in tanning.

Tanners in Europe also are becoming more and more dependent upon imported materials. European importations include a larger proportion of raw barks and woods, due to a slower development of extract tannage on that continent.

The extended use of mangrove bark, and more particularly mangrove extract, is of comparatively recent development. The East African swamps ⁴ have for a number of years furnished bark, chiefly for the German market. Twelve thousand two hundred and sixty-three tons, to the

¹ This paper is a continuation of the work begun by R. F. Bacon and Vicente Q. Gana of this Bureau. See *This Journal Sec. A* (1909), 4, 205.

² Commerce and Navigation of the United States. *U. S. Bur. Statistics* (1900-1910).

³ Tan bark and Tanning Extract in 1908. *Bull. U. S. Bur. Census, Forest Products* (1911), No. 4, March.

⁴ *Board of Trade Journ.* (1905), Mar. 9, through *Journ. Soc. Chem. Ind.* (1905), 24, 298.

value of 250,409 dollars, found their way to American ports in 1909. The swamps of the Malayan region also have been a considerable source of supply. These barks, although of the same species as the East African, contain only 25 to 30 per cent of tannin as compared with 35 to 40 per cent in the latter. For this reason, exports have been limited to the manufactured extract known as cutch. A number of companies have successfully been operating in Borneo, Java, and Sumatra for several years. American tanners bought 700 tons of this extract in 1909, at a cost of 43,566 dollars. The article entered the United States duty free until March 1906 (Treasury Decision No. 27197) when it was declared dutiable. This caused a general decrease in production and closed one Borneo factory. Under the Payne tariff of 1909 cutch is dutiable at seven-eighths of a cent per pound.

The advantage which the Philippines enjoys in this respect promises to give opportunity for a profitable cutch industry in the Archipelago. All the species of mangroves of any importance in the Eastern tropics are found in the Philippines. The area of the swamps, though small compared with those of Borneo, Sumatra, and the Malay Peninsula, is considerable. The Bureau of Forestry estimates the total virgin swamps of the Philippines at 207,200 hectares, which includes an area of 25,000 hectares of well-developed swamps in Sibuguey Bay, Mindanao, a 10,000-hectare tract in Mindoro, and a fairly compact area of good swamp in Palawan; but on other islands than the three mentioned the swamps are so scattered as to render profitable cutch manufacture very doubtful. The swamps of Tayabas and the Sulu Archipelago should perhaps be excepted.

"In ^s Mindoro, Palawan, and Mindanao, the *Rhizophoracæ* reach as large size as anywhere in their range. *Sonneratia* also seems to reach its maximum development in Mindanao."

Only a few carefully estimated figures are to be found upon the tannin content of mangrove barks. Analyses made near the source of supply have not to any extent been published. Apparently, samples analyzed elsewhere frequently have lost much of their tannin before reaching the chemist. Busse ⁶ reports analyses of some East African barks and gives for comparison those of barks from the same region made by the "Deutsche Gerberschule zu Freiburg."

	Tannin (per cent).	
	Berlin (Busse).	Freiburg.
<i>Bruguiera gymnorhiza</i> Lam.	51.64	24.60
<i>Ceriops candolleana</i> Arn.	42.27	27.50
<i>Xylocarpus granatum</i> or <i>X. obovatus</i>	40.49	8.70
<i>Rhizophora mucronata</i> Lam.	47.99	21.30

⁵ Foxworthy, F. W. Distribution and Utilization of the Mangrove Swamps of Malaya. *Ann. Jard. Bot., Supplement III*, Buitenzorg (1909), II, 319.

⁶ *Arb. a. d. kais Gsndhtsmt.* (1899), 15, 177-184.

He attributes the low results of the Freiburg school to improper packing for shipment.

Two¹ analyses of *Rhizophora mucronata* Lam. from Zanzibar show 34.3 and 35.8 per cent of tannin in barks containing 16.2 and 16.4 per cent moisture, respectively. Blockey² reports some analyses of Indian mangrove barks as follows:

	Tannin (per cent).
Bruguiera gymnorrhiza	9.7
Kandelia rheedii	17.3
Rhizophora mucronata	{ 4.5 6.1
Ceriops candolleana	18.0

Various trade notes give the barks of India as averaging 25 to 29 per cent of tannin, which doubtless is more nearly correct. The results of the Freiburg school and those of Blockey certainly do not represent the average barks of the two regions.

The Philippine Bureau of Forestry has furnished the following report upon four samples of Philippine barks submitted to the Bureau of Plant Industry at Washington.

	Total solids.	Soluble solids.	"Reds"	Non- tannin.	Tannin.
No. 15335 B. F. (<i>Ceriops tagal</i> (Perr.))	58.58	49.02	9.56	13.19	35.83
No. 15336 B. F. (<i>Rhizophora conjugata</i> L.)	53.91	51.03	2.88	11.64	39.39
No. 15337 B. F. (<i>Bruguiera eriopetala</i> W. & A.)	37.36	36.81	0.55	10.15	26.66
No. 15338 B. F. (<i>Bruguiera parviflora</i> W. & A.)	24.43	19.82	4.61	7.27	12.55

EXPERIMENTAL.

The swamp area of the east coast of Sibuquey Bay, Mindanao, from the mouth of the Vitali River to that of the Bulaan, a distance of some 40 miles, has been taken as representative in a general way of the better swamps of the Philippines. Different species predominate in different areas and there are of course considerable variations in the stands of timber. However, in the matter of the tannin content of the bark of any given species, no considerable variation is to be expected in Philippine swamps of approximately equal development.

I have found that this area will yield about 20 metric tons per hectare of fresh bark of mature trees of selected species averaging about 28 to 30 per cent of tannin on the dry weight. Only four species are included in this estimate, all others being negligible from a commercial

¹ Bull. Imp. Inst., London (1904), 2, 163-166.

² Journ. Soc. Chem. Ind. (1902), 21, 158.

standpoint. The natural resources are sufficient for a profitable industry, the swamps being fully as valuable, hectare for hectare, as many now being worked in the East Indies.

It has further been observed that, in general, the tannin content of the bark increases with the size of the tree. It is probable that the age rather than the size of the tree is the true coefficient of the tannin content, but since these trees show no seasonal rings of growth it is almost impossible more than roughly to approximate the age. Such variations from the general rule as will be observed in the tables given below, where the approximate diameters are noted, are easily accounted for by differences in the conditions of growth of the individual trees. However, further work must be done to establish the fact.

Like many other barks, these deteriorate when allowed to dry slowly in the air. Molds may grow on the fresh bark and rapidly destroy the tannin. Exposure to the air and light in any case causes oxidation, resulting in loss of tannin and production of red coloring matter. All samples, the analyses of which are given below, were dried over quick lime and placed in dark, air-tight bottles until analyzed. The analyses in all cases were made within sixty days after collection. Samples collected near Manila, dried and preserved in this manner, at the end of two months showed no losses of tannin exceeding 0.5 per cent. The analyses were made by the method of the Association of Official Agricultural Chemists, substantially as published in Bulletin No. 107 of the United States Bureau of Chemistry. Somewhat larger quantities of hide powder than those recommended were found necessary completely to detannize the solutions.

Data, both analytical and general, regarding the principal trees of the swamps are given below. Botanical descriptions⁹ have not been included.

***Rhizophora mucronata* Lam. BACAUAN (Tagalog).**

This tree is found in stands of even development, usually on the water side of the swamp. It makes up two-fifths to one-half of the total timber producing commercially valuable bark. Its maximum diameter is 50 centimeters; the average 25 to 30 centimeters, excluding young trees below 20 centimeters in diameter. It attains a height of 15 to 25 meters. Three average-sized trees were found to yield 140 kilograms each of fresh bark. The bark bears a thin, hard, outer scale easily removed from the inner bark, which is orange colored, nonfibrous and somewhat pulpy, and contains 50 to 60 per cent of moisture. The wood is hard and heavy (specific gravity about 1.1 when dry), and is reddish in color. It is an excellent firewood and well adapted for

⁹ Foxworthy, F. W., *Loc. cit.* Also Hooker, *Flora of British India*, and Schimper, *Indo-Malayische Strand-flora*.

structural uses in wet places. Analyses show 4 to 6 per cent tannin. The leaves assay about the same.

TABLE I.—Analyses of bark of *Rhizophora mucronata* Lam.^a

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	Cm.				
1 -----	23	60.4	39.6	15.7	23.9
9 -----	23	60.8	39.2	13.7	25.5
10 ^b -----	13	68.5	31.5	15.7	15.8
11 ^b -----	15	75.7	24.3	12.0	12.3
18 -----	20	67.6	32.4	11.1	21.3
28 -----	30	65.0	35.0	14.6	20.4
45 -----	32	59.1	40.9	14.7	26.2
60 -----	25	58.6	41.4	12.5	28.9
63 -----	22	58.0	42.0	11.4	30.6
64 -----	23	54.3	45.7	11.9	33.8
65 -----	25	56.2	43.8	14.9	28.9
66 -----	30	60.0	40.0	13.0	27.0
69 -----	30	61.2	38.8	12.4	26.4
72 -----	45	56.6	43.4	12.9	30.5
73 -----	20	63.9	36.1	15.3	20.8
80 -----		57.0	43.0	12.7	30.3
81 -----		55.2	44.8	15.0	29.8
82 -----		56.4	43.6	11.2	32.4
83 -----		56.4	43.6	11.8	31.8
84 -----		55.1	44.9	15.8	29.1
85 -----		61.8	38.2	11.8	26.4
86 -----		61.0	39.0	12.7	26.3
87 -----		58.5	41.5	13.3	28.2
Average -----		59.2	40.8	13.2	27.6

^a An average tree will yield bark to the value of 4.97 pesos, at 0.286 peso per kilogram. One ton of fresh bark is worth 35.50 pesos. The peso Philippine currency is equal to fifty cents United States currency; 0.286 peso per kilogram equals 0.065 dollar, per pound.

These figures do not represent the value of the bark as such, but of the total tannin present at the current price of tannin extracts. (Letter of A. Klipstein & Co., New York, July 22, 1910). They are given for the purpose of comparing the various barks.

^b Excluded from average as undersized tree.

A composite of the above samples gave 2.8 per cent "difficulty soluble" tannins or "reds."

Rhizophora conjugata Linn. BACAUAN (Tagalog).

This tree in every way is similar to the preceding, but is much less common, amounting perhaps to one-tenth of the bark-producing timber. The bark is somewhat lighter in color when fresh than that of *Rhizophora mucronata*, while the woods of the two species are practicably indistinguishable.

TABLE II.—Analyses of bark of *Rhizophora conjugata* Linn.^a

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	Cm.				
15.....	27	62.8	37.2	10.3	26.9
16.....	32	58.0	42.0	9.6	32.4
48.....	27	63.0	37.0	10.7	26.3
51.....	22	55.3	44.7	16.3	28.4
52.....	32	56.2	43.8	17.3	26.5
53.....	30	58.8	41.2	15.4	25.8
54.....	30	54.1	45.9	14.8	31.1
55.....	25	60.7	39.3	12.5	26.8
61.....	25	59.9	40.1	13.4	26.7
Average.....	27.7	58.8	41.2	13.4	27.8

^a An average tree will yield bark to the value of 5 pesos. One ton of fresh bark is worth 35.77 pesos. See footnote "a" to Table I.

A composite of the nine samples shows 1.9 per cent of "reds."

***Bruguiera gymnorrhiza* Lam. and *B. eriopetala* W. & A.**

Both these species are known by the native name *pototan* or *pitutan*. They can be distinguished only by their flowers, the most obvious difference being in their color. Those of *Bruguiera gymnorrhiza* Lam. are red; of *Bruguiera eriopetala* yellow. When the samples were taken, in most cases flowers were not visible and the two species therefore have been taken together. They constitute about 20 to 30 per cent of the workable trees. The maximum diameter is 1 meter; the average diameter 40 to 45 centimeters, excluding trees under 20 centimeters. Three average-sized trees yielded 190 kilograms each of fresh bark. The scale is dark, about 5 millimeters thick, and adheres rather strongly to the inner bark. The latter is of a dark orange-color, somewhat fibrous, and contains 40 to 50 per cent moisture. The wood is like that of the other *Rhizophoraceae*, but is more valuable because of the size of the trees. It contains 6 to 8 per cent of tannin.

TABLE III.—Analyses of *Bruguiera gymnorhiza* Lam. and *B. eriopetala* W. & A.^a

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	<i>Cm.</i>				
22.....	50	63.0	37.0	8.5	28.5
23.....	60	51.2	48.8	9.8	39.0
29.....	60	51.6	48.4	11.0	37.4
32.....	35	58.4	41.6	13.9	27.7
33.....	60	50.3	49.7	11.8	37.9
37.....	75	51.5	48.5	11.9	36.6
40.....	30	70.7	29.3	7.2	22.1
42.....	37	60.9	39.1	9.7	29.4
46.....	30	63.8	36.2	9.0	27.2
49.....	37	55.8	44.2	12.2	32.0
58.....	50	64.8	35.2	7.0	28.2
67.....	70	46.5	53.5	11.8	41.7
75.....	40	53.4	45.6	12.3	33.3
Average.....	46.5	57.2	42.8	10.4	32.4

^a An average tree will yield bark to the value of 9.70 pesos. One ton of fresh bark is worth 51 pesos. See footnote "a" to Table I.

A composite of above samples showed 0.3 per cent "reds."

Bruguiera parviflora W. & A.

The common name is *lañgaray* or *hagalay*. It is a tall, slender tree growing in very even stands and very plentifully. Its maximum diameter is about 30 centimeters, the average diameter 20 to 22 centimeters. An average-sized tree yielded 100 kilograms of fresh bark of dark red color, very fibrous in structure, and containing 35 to 40 per cent of moisture. The wood is lighter in color and weight than *bacauán* and *pototan* and somewhat softer. It contains 1 to 2 per cent of tannin.

TABLE IV.—Analyses of bark of *Bruguiera parviflora* W. & A.^a

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	<i>Cm.</i>				
6.....	20	81.4	18.6	8.0	10.6
12.....	22	87.2	12.8	5.6	7.2
20.....	25	86.5	13.5	6.1	7.4
21.....	25	85.1	14.9	6.8	8.1
30.....	25	84.4	15.6	7.0	8.6
31.....	35	82.8	17.2	8.8	8.4
38.....	25	78.3	21.7	8.6	13.1
41.....	30	85.4	14.6	5.9	8.7
59.....	22	82.4	17.6	6.9	10.7
62.....	30	78.8	21.2	8.8	12.4
70.....	22	84.3	15.7	7.3	8.7
71.....	20	85.7	14.3	7.7	6.6
74.....	30	81.6	18.4	10.0	8.4
76.....	20	85.7	14.3	6.6	7.7
Average.....	25.0	83.6	16.4	7.3	9.1

^a An average tree will yield bark to the value of 1.63 pesos. One ton of fresh bark is worth 16.30 pesos. See footnote "a" to Table I.

A composite of the above samples showed 5.6 per cent of "reds."

Ceriops tagal (Perr.) C. B. Robinson. TAÑGAL (Tagalog).

Tañgal is now scarce in the Sibuguey Bay region. Its bark is highly prized by the natives for coloring rice and "tuba," and for dyeing. The wood is also of more value than any other mangrove. The charcoal supply of the Islands largely is made from it. Commercially, it is a negligible factor in this region.

TABLE V.—Analyses of bark of *Ceriops tagal* (Perr.) C. B. Robinson.

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	<i>Cm.</i>				
8.....	15	54.5	45.5	11.8	33.7
34.....	37	51.7	48.3	11.1	37.2
35.....	12	59.2	40.8	17.0	23.8
36.....	30	54.0	46.0	14.7	31.3
39.....	30	58.9	41.1	10.6	30.5
Average.....	25.0	55.7	44.3	13.0	31.3

Xylocarpus granatum Koen. PIAGAO (Tagalog).

This tree often reaches 50 centimeters in diameter, but it is not very plentiful. Its bark is exceedingly thin, usually 2 to 3 millimeters; it is dark on the exterior and bright red on the interior. A tree will not yield more than 20 to 25 kilograms of bark. Its wood shows 6 to 8 per cent of tannin. The wood is very beautifully grained and colored, and should be valuable for interior finishing.

TABLE VI.—Analyses of bark of *Xylocarpus granatum* Koen.

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract	Non-tannin.	Tannin.
	<i>Cm.</i>				
7.....	20	62.8	37.2	12.2	25.0
57.....	45	70.0	30.0	9.1	20.9
Average.....	32.5	66.4	33.6	10.6	23.0

Xylocarpus obovatus A. Juss. TABIQUE or NIGUÉ (Tagalog).

In some of the higher parts of the swamps this tree occurs quite plentifully, attaining a diameter of 30 to 40 centimeters. Its bark, like that of the preceding, is very thin. Its wood is somewhat lighter in color and weight than *X. granatum*. The trees often are decayed at the heart.

TABLE VII.—Analyses of bark of *Xylocarpus obovatus* A. Juss.

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract	Non-tannin.	Tannin.
	<i>Cm.</i>				
78.....	25	67.6	32.4	7.7	24.7
79.....	20	69.7	30.3	8.6	21.7
Average.....	22.5	68.7	31.3	8.1	23.2

Sonneratia pagatpat Blanco. PAGATPAT (Tagalog).

These trees often grow in exposed places, and under such conditions are stunted and gnarled. Under more favorable surroundings they sometimes exceed 1 meter in diameter. The bark is dry and woody, sometimes containing only 15 to 20 per cent of moisture in old trees. The wood is yellow-white but dark at the heart. It is moderately hard, suitable for general structural work.

TABLE VIII.—Analyses of bark of *Sonneratia pagatpat* Blanco.

Sample No.	Diameter of tree.	Parts per 100 of water-free material.			
		Insoluble.	Total extract.	Non-tannin.	Tannin.
	<i>Cm.</i>				
13.....	50	82.3	17.7	5.6	12.1
14.....	50	80.7	19.3	7.3	12.0
44.....	82	80.1	19.9	7.6	12.3
56.....	20	81.4	18.6	7.8	10.8
Average.....	50.5	81.1	18.9	7.1	11.8

A survey of the data shows that only four species can be depended upon to furnish a supply of bark. They are *Rhizophora mucronata*, *R. conjugata*, *Bruguiera gymnorhiza* and *B. eriopetala*, the two former commonly known as "bacauan," the two latter as "pototan" or "pitutan." Tañgal, which is the "teñgah" bark of Borneo upon which the manufacturers there depend to a considerable extent, is scarce on Sibuguey Bay. Both *Xylocarpus granatum* and *X. obovatus* yield too small quantities of bark per tree to be remunerative. *Bruguiera parviflora* has a very low tannin content, as has *Sonneratia pagatpat*.

However, a use may be found for the last mentioned for blending with the more valuable barks, since it produces a leather of good, brown color, very different from any tanned by barks of the *Rhizophoraceæ*. Some samples of leather were tanned with well-preserved barks by the method suggested by Parker and Procter,¹⁰ using goat skin instead of sheep grain, as the latter was not obtainable in Manila.

No.	Tanning material.	Description of leather.
1	Bacauan.....	Dark red, somewhat thick grain.
2	Pototan	Not distinguishable from No. 1.
3	Pagatpat	Medium brown, porous, soft, smooth grain.
4	<div style="display: inline-block; vertical-align: middle;"> {Bacauan..... Pototan</div> } equal parts --	<div style="display: inline-block; vertical-align: middle;"> {Reddish brown, better than either Nos. 1 or 2, grain smooth. </div>
	Pagatpat	

In calculating the yield of bark in the area examined, only bacauan and pototan trees 20 centimeters or more in diameter have been counted. For this purpose seven rectangular areas of about one-fourth hectare each were selected as representative after a fairly thorough exploration of the surrounding swamp. These areas are distributed at approximately regular intervals between the mouths of the Vitali and Buluan Rivers.

¹⁰ Parker, J. C., & Procter, H. R. Numerical expression of color. *Journ. Soc. Chem. Ind.* (1895), 14, 125.

The yield of bark per tree was determined by felling three representative trees each of bacauan and pototan and stripping and weighing the bark. Bacauan averaged 140 kilograms per tree, pototan 190 kilograms. On this basis the area will yield 20.6 metric tons of bacauan bark per hectare, and 5.8 tons of pototan. We may safely state the yield at 20 tons per hectare of bark worth about 40 to 45¹¹ pesos per ton, at 0.286 peso per kilogram unit of tannin, allowing 50 per cent for moisture.

The restrictions placed by the Bureau of Forestry upon the exploitation of the swamps will depend largely upon their condition at the outset. However, it is understood that in virgin swamps the cutting of trees over 20 centimeters in diameter will be permitted provided the wood is put to some commercial use. It is said that in Borneo and Queensland the standing trees are stripped as high as convenient and the tree left to die and go to waste. I am convinced that the bark can be gathered more economically by felling the tree and obtaining all the bark. A tax of 3 pesos per metric ton is levied on the dry bark.

It is not my purpose to take up the question of the disposal of the wood. This problem certainly is the most serious one confronting the prospective exploiter of swamps distant from Manila. The market for mangrove woods for structural purposes at present is extremely limited. The firewood industry has been suggested as an outlet. Taxes were paid on about 200,000 cubic meters of firewood in 1909. However, most of this supply comes from swamps near the markets for which it is intended. It sells on an average all over the islands for about 25 pesos per 1,000 *rajas* (about 5 to 6 cubic meters). After paying for logging, sawing, splitting, and meeting transportation charges of at least 1.50 to 2 pesos per cubic meter and a tax of 1 peso there would be an exceedingly small profit even if present prices could be maintained.

If a market can not be found for the wood, destructive distillation might be resorted to, as there is every reason to believe that these woods are especially suitable for that purpose. The lack of a near market for large quantities of charcoal would of course be a great drawback. Aside from this, there can be no question but that such swamps can be exploited at a good profit.

Shipment of the raw bark might not prove profitable. Mangrove barks are quoted¹² at 18 dollars per ton in the United States. This is an extremely low price per unit of tannin, even in crude materials. It is probably due to the high coloring power of air-dried barks. It is possible that by kiln drying a better price might be obtained. However, Australia offers a much better market for such materials. The demand is steady and the better classes of tan barks bring as much as 7 pounds

¹¹ This is not the market value of the bark as such. See footnote "a" to Table I.

¹² Hide and Leather, Oct., 1910.

sterling per ton. Freight charges to Australia from the Philippines are also very much lower than they are to the United States. I estimate the cost per ton of dry bark, as follows:

	Pesos.
Felling and stripping	8.00
Delivery at kilns	2.00
Drying	1.50
Tax	3.00
Freight (Australia)	12.50
Total	27.00

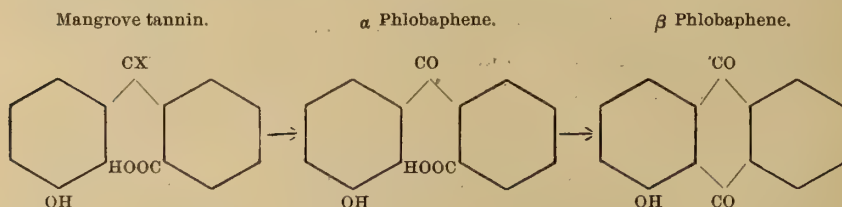
CUTCH MANUFACTURE.

Cutch is prepared by extracting the bark with water and evaporating the liquor to a suitable percentage of moisture. Cutch prepared by the best methods now in use has approximately the following composition and characteristics:

	Per cent.	
Water	20	
Tannin	50 to 55	
"Insolubles"	2 to 5	
Nontans	{ Ash	1 to 2
	{ Sugars	5 to 7
	{ Organic	} 16 to 18
	{ Acids, etc.	

The extract produces a reddish-brown leather, somewhat harsh and thick-grained, due to the high astringency of the tannin; but it gives a very satisfactory tannage when mixed with other materials.¹³

The tannin, coloring matter, "insolubles," and nontans, each plays a part in the tanning process. Mangrove tannin is a "greening tannin" of the pyrocatechol series. Its empirical formula is generally accepted as $C_{24}H_{28}O_{12}$. It is a derivative of the dihydroxy phenol catechol. Closely related to the tannin are the red coloring matter and the insolubles. Nierenstein and Webster¹⁴ express the relationship by the equation:



The more soluble, red colored substance is produced by oxidation, and this, by the splitting off of water, forms the less soluble phlobaphene which constitutes the bulk of the so-called "reds" which deposit as a slime upon cooling extract liquors. It is certain in any case that the tannin is the source of the red

¹³ *Collegium* (1902), 322-324; *Ibid.* (1904), 15-16. Also *Bull. Imp. Inst.*, London (1904), 2, 163-166.

¹⁴ Nierenstein and Webster, *Collegium*, 1909, 337.

colored bodies. The soluble coloring matter, like the tannin, is absorbed by the hide to form true leather. The insolubles play a useful part in the latter stages of tanning by mechanically impregnating the surface of the hide and thus rendering it heavier and more impervious to water. More often than otherwise they are present in excess of the needed quantity and in that case are a nuisance to the tanner. If present in the more dilute liquors in which the hides are first immersed, they deposit in the pores or on the surface of the goods and prevent the proper diffusion of the soluble materials into the interior of the hide.

The rôle of the nontans is quite a different one. Such glucosidal matters as are present ferment to form acids, chiefly lactic and acetic, which are necessary to keep the hide open and promote the diffusion of the tannin. If not present in sufficient amount, either acid or acid-forming material must be added. Pyrocatechol tannins are frequently deficient in this particular, the nontans being composed largely of salts. The¹⁵ latter play no considerable part in tanning except that the presence of large quantities may be deleterious to the color and¹⁶ grain.

Therefore, in the manufacture of an extract it is desirable to reduce the coloring matters, the "insolubles," and the metallic salts to a minimum and to obtain the maximum concentration with the minimum loss of tannin. The methods in use in Borneo are regarded as trade secrets by the manufacturers; however, they are known¹⁷ in a general way, and the process presents no great difficulties.

Other things being equal, fine grinding promotes thorough extraction, especially if it be carried out at a low temperature; but for various reasons, fresh bark must be used and fine grinding of this material would be difficult. On this account I believe a preliminary kiln drying of the bark would be advisable, as it could be done cheaply and would make possible the use of much cheaper mills.

Extraction can best be done in wooden vats, using fresh water for the nearly exhausted barks and liquors of higher concentration for the less completely extracted material. With coarse bark the temperature would necessarily be high in order to break up the cells and give a thorough extraction. For finely ground material 50° to 60° is preferable. Parker and Procter¹⁸ have shown that water at this temperature extracts more tannin and less coloring matter from most materials, and among them mangrove bark, than at higher temperatures. These comparisons were of infusions made by exhaustive extractions at various temperatures.

It was thought by me that most of the tannin might more readily be extracted at some other temperature. Experiments were made with *Rhizophora mucronata* and *Bruguiera eriopetala*.

Five grams of finely ground bark were treated two and one-half hours with 100 cubic centimeters of distilled water, the whole thrown on a sand filter and

¹⁵ Parker, *Journ. Soc. Chem. Ind.* (1900), 19, 313-315.

¹⁶ Jean, *Rev. Chim. Ind.* (1896), 7, 269-271.

¹⁷ U. S. 60th Cong. House Doc. 1505, 1, 221-228.

¹⁸ Parker, J. G., and Procter, H. R., *Journ. Soc. Chem. Ind.* (1895), 14, 635.

washed with 50 cubic centimeters of water at the temperature of extraction. The solutions were made up to 250 cubic centimeters and analyzed. Color comparisons were made in Nessler cylinders with dilute solutions and calculated to a uniform tannin content.

TABLE IX.—*Extraction of bark of Rhizophora conjugata Linn. at various temperatures.*

No.	Temperature.	Tannins extracted.		Color, per cent of maximum.
		Per cent of maximum.	Per cent of total.	
1.....	30	89.0	74.1	70
2.....	60	100.0	83.0	75
3.....	80	88.8	73.8	90
4.....	Boiling.	75.2	62.8	100

TABLE X.—*Extraction of Bruguiera eriopetala W. & A. at various temperatures.*

No.	Temperature.	Tannins extracted.		Color, per cent of maximum.
		Per cent of Maximum.	Per cent of total.	
1.....	30	95.5	72.1	97.0
2.....	60	96.6	73.0	97.0
3.....	80	96.1	72.7	98.0
4.....	Boiling.	100.0	75.5	100.0

The results show that pototan (Table X) is little affected by the temperature, while bacauan (Table IX) is best treated at 60°.

A large number of expedients were tried for clarification of the liquors. Moderately concentrated liquors upon cooling deposit a considerable part of the resinous "insoluble" substances within a few hours. Neither clay nor alumina increase the amount of "reds" precipitated nor hasten the subsidence. They do cause small losses of tannin. Animal charcoal is worthless. A dilute solution of albumen aids the clarification slightly, but causes some loss of tannin. Nothing as practical as simple cooling and subsidence has been found.

Suggestions and patent processes for dissolving the "reds" and bleaching tan liquors are very numerous. The problem presents many difficulties both because of the great ease with which tannins are precipitated or otherwise destroyed by very many chemical reagents and because of the intimate relation existing between the bodies which are to be separated.

Sulphurous acid was the first reagent tested by myself. Although of some value in treating certain extracts, it is worthless for that of mangrove. Neither at high nor low temperatures or pressures does it pro-

duce any brightening effect without the precipitation of large quantities of tannin. Carbon monoxide does not cause loss of tannin, but its bleaching effect is slight and not permanent. The method of Lepetit, very successfully used for "sulphiting" quebracho, destroys some tannin and neither bleaches nor clarifies. Sodium bisulphite was used in this test and the liquor was heated in an autoclave for eight hours at a temperature of 115° to 120° . Alkaline salts and hydroxides, such as sodium sulphite, borax, ammonia, caustic soda and the like, dissolve the "insolubles" readily. As an alkaline liquor can not be used for tanning, these reagents are useless. However, it was found that treatment with a dilute alkali under pressure at 110° to 120° for three to six hours rendered the "reds" quite soluble in acid solution. Neither acetic, lactic, nor sulphurous acid precipitated them even after several hours' standing. Evaporation to dryness once more rendered them insoluble. It is particularly noteworthy that although the tannin of the treated extract was not destroyed by sulphurous acid, as was the case with the untreated material, there was no appreciable brightening of the liquor. Such an extract gives a nearly black leather and is unserviceable for tanning.

Nascent hydrogen is the best bleaching agent so far found. It is best generated with aluminum shavings and sulphuric acid, as the presence of small quantities of aluminum sulphate is not detrimental to the extract. The aluminum should be in excess so as to leave no acid to attack metal evaporating vessels. If the liquor is extremely dark and much acid must be added to bleach it, the bulk of the reagents in solution can be removed with baryta water. However, care should be taken that alkalinity is not reached, for the liquor will then darken more rapidly on evaporation and the leather is more likely to be stained by the barium hydroxide present.

By this method the "reds" are dissolved to a slight extent and the remainder coagulate and settle with the barium sulphate. An extract so treated gives a leather of good color, which darkens comparatively little on exposure to air.

Patents have recently been taken out for two processes especially designed for mangrove extract. One of them by Damkohler u. Schwindt (Eng. Pat. 24899, Oct. 29, 1909),¹⁹ is based on the action of the "nascent hydroxides of metals" which are generated by electrolysis. A nonelectrolytic process included in the same patent is that of adding barium aluminate to the extract, and afterwards sulphuric acid or sulphates to clear the liquor. The complete specifications for the patent are not obtainable in Manila so that it was not thought worth while to test the electrolytic method. However, the nonelectrolytic process promises very well from the tests made with it. An extract so treated gave an excellent light-colored leather.

¹⁹ Abstracted in *Journ. Soc. Chem. Ind.* (1910), 29, 365.

Another process designed by the Deutsche Versuchsanstalt für Lederindustrie u. H. Arnoldi (Ger. Pat. 220, 221, Sept., 1908)²⁰ is especially recommended for mangrove extract. It makes use of the action of aluminium amalgam. This process gave a more unsatisfactory result in my experiments than the one mentioned above. Leather produced from it was dark, although of smooth grain. No final conclusion can be reached until a fuller description of the process is obtained. With proper investigation one or more of the three methods last mentioned may confidently be expected to prove serviceable for commercial use.

TABLE XI.—*Effect of various methods of treatment of cutch.*

	Wa- ter.	Tan- nin.	Non- tans.	In- solu- bles.	Total ex- tract. ^a	Color of leather.
					Grams.	
Untreated extract.....	0.0	62.8	32.0	5.2	-----	Medium red.
0.2 per cent NaOH acid- ified with SO ₂	0.0	53.5	40.1	6.4	104.0	Nearly black.
Al+H ₂ SO ₄	0.0	55.0	45.0	0.0	108.0	Yellowish brown.
Barium aluminate.....	0.0	59.3	40.7	0.0	-----	Light reddish brown.
Aluminium amalgam..	0.0	58.6	41.4	0.0	-----	Medium red.

^a This is the weight of extract obtained from 100 grams of the original material, calculated to the dry weight.

Dialysis through a suitable membrane suggests itself as a means for diminishing the quantity of metallic salts present. Such a treatment is not essential to producing a good tanning material and would be of no great value except in giving a greater concentration of tans. Moreover, the process is an extremely slow one. Two thousand five hundred cubic centimeters of a 20 per cent solution of extract were dialysed for thirty hours with a continuous change of water over the diaphragm. The diaphragm was made by depositing a film of collodion on cheese-cloth. It had an area of about 100 square centimeters. At the end of the process only 12.85 per cent of the mineral matter had been removed. The loss of tannin was very small.

The liquors properly treated, in as great a concentration as it is possible to obtain them in the process of extraction, should be evaporated *in vacuo* to a solid. Possibly, the earlier portion of the evaporation can be carried out by boiling in tall vessels with converging sides, such as will keep the liquor well protected from the air by a layer of water vapor. However, the last portions of the water must be removed by vacuum evaporation.

It is not possible to estimate the cost of the equipment for a plant with any accuracy from data now in our hands. The vacuum evapo-

²⁰ Abstracted in *Chem. Abs. Amer. Chem. Soc.* (1910), 4, 2588.

rators will make up the larger part of this expense. A suitable evaporator to handle 3 to 4 tons of solid extract per day of twenty-four hours would cost 35,000 to 40,000 pesos. The other parts of the plant could be put up for an equal or less amount.

The cost of manufacture need not be great, as extremely cheap fuel and labor are available. Fresh bark should not cost more than 8 pesos per ton. On a basis of 50 per cent moisture and a 90 per cent extraction, 4.3 tons of this bark will produce 1 ton of cutch, worth 140 to 150 pesos. It is believed that at present prices a net profit can be made of 50 to 60 pesos per ton. As there is a large demand for the product, its manufacture offers a promising field for investment.

Further data and suggestions as to manufacture can be furnished to prospective investors.

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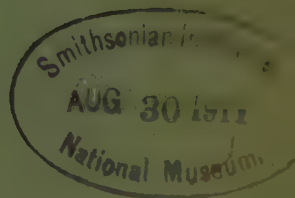
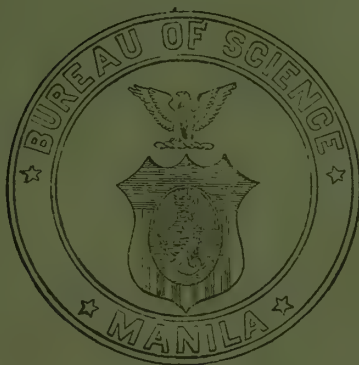
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No. 2

THE ERUPTION OF TAAL VOLCANO, JANUARY 30, 1911.

By WALLACE E. PRATT.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

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INTRODUCTION.

The active volcano Taal in southwestern Luzon, began throwing out steam and mud on January 27, 1911, and continued in eruption with increasing violence during January 28 and 29, culminating in an explosive outburst early on the morning of January 30, which laid waste the surrounding country over an area of 230 square kilometers, killing practically all life within this area. Mud or ashes spread over more than 2,000 square kilometers in southwestern Luzon. The activity diminished gradually to a state of normal quiescence by February 6 to 8.

Sources of information.—This paper embodies personal notes made during the two weeks immediately succeeding the eruption. In this time every part of the devastated region was visited. Information as to

what happened on the night of the eruption was secured by conversations with people who had witnessed it at close range from different points of view. On January 30, the writer went to Bañadero, a town near the volcano, and during a large part of the subsequent field work Mr. Charles Martin, photographer of the Bureau of Science, was with him. Mr. Martin also was on Volcano Island just before the main eruption.

Location and brief description of Taal Volcano.—Taal Volcano near the center of Lake Bombon may be said to constitute an island with the active crater centrally located on it. Its rim is low, varying from 100 to 320 meters in elevation. Its floor stood just above sea level prior to this last eruption. The volcano is about 60 kilometers south of Manila. The crater has an area of about 3 square kilometers, the island contains about 25 square kilometers, and Lake Bombon covers an area of approximately 320 square kilometers. Each is roughly oval in general outline. There were seven small *barrios* (villages) on the island and Lake Bombon was fringed with the homes of native fishermen and sugarcane planters. Attention is directed to Plates I and II, and text figure No. 1, in connection with these details of location.



TEXT FIG. NO. 1.

There is no evidence that lava ever flowed from Taal Volcano. The crater walls, the island, and the whole surrounding country are composed of bedded volcanic tuff and agglomerates. Volcano Island contains a number of small extinct craters or cinder cones and it is generally conceded that volcanic activity formerly covered the whole area of the present lake, either as a single great crater or more probably, perhaps, as a large number of smaller craters. For a concise discussion of Taal Volcano, its geology and historic eruptions, the reader is referred to the work of Dr. George I. Adams.¹

THE ERUPTION.

Narrative.—The first intimation of the approach of the recent eruption was obtained from the increased size of the cloud of steam which always hangs over the active crater, and also from mild earthquakes. People as far away as Batangas (about 30 kilometers distant) began to be alarmed by these conditions on Friday, January 27. The earthquakes increased rapidly in violence and number and on the following day the immense white cloud quite plainly visible from Batangas was frequently blackened by the ejection of mud. The cloud rose in explosive outbursts, which were often immediately preceded by a perceptible earthquake shock.

A noticeable amount of mud² had already fallen on the slopes of the volcano when Mr. Martin reached the island on Sunday morning, January 29. At about 3.30 Sunday afternoon large cracks opened in the earth near the towns of Lemery and Taal. Probably also the small fissure at Talisay appeared at this time. There were fewer earthquakes recorded on Sunday than on the previous day, although severe shocks accompanied the appearance of the earth fissures. Apparently, the activity of the volcano was slightly lessened on Sunday afternoon.

A number of people were on the lake shore on Sunday night and had an unobstructed view of the eruption. From the experience of several of these eyewitnesses, the following main points are presented.

The activity began to increase again about dark with violent outbursts from the volcano and sharp earthquakes. About 11 o'clock in the evening a very severe earthquake was followed closely by the ejection of a massive black cloud from the volcano. From this time on, it appears, the cloud above the volcano was very frequently crossed and streaked with lightning, and often showed flashes or sheets of light. Some people saw incandescent bodies rising out of the crater and falling in graceful curves to the earth. At 1 o'clock in the morning, another outburst occurred, probably more violent than the one at 11 o'clock, but similar to it. At 2.20 o'clock in the morning, without any severe earthquake, but accompanied by a loud noise, resembling an explosion, the culminating outburst of the eruption took place. The great black cloud shot up higher than before and finally spread out at the top like an "umbrella," or a "giant cauliflower." The lightning became much more intense, there was much explosive noise and at some places, such as Talisay and San Nicolas, a strong wind came from the volcano. At Bañadero there was little wind, but mud began to fall. Very soon

¹Geological Reconnaissance of Southwestern Luzon. *This Journal*, Sec. A (1910), 5, 57.

²Fine sand or "ash," which, where dry, was light gray in color.

the lake suddenly rose about 2.5 meters. The mud at Bafiadero was cool and fell like rain. The activity decreased gradually, and by daylight the cloud from the volcano was again white.

This main eruption awakened many people in Manila, and in Dagupan, 240 kilometers north of the volcano, people say they were awakened at about this time by hearing a noise. The effect in Manila was that of a tremendous vibration, accompanied by the rattling of windows and loose doors. The noise seemed to pass over the city in a great wave, so that it was heard farther away, after it had ceased close at hand. No earthquake was recorded in Manila at this time.

Eruption cloud.—The cloud which rose over Taal Volcano during the recent eruption, seems to have been like those noted over other volcanoes during similar times. It emerged from the crater with explosive violence, rose rapidly in the air to a great height, and finally spread out at the top in a horizontal layer.

No observations were made as to the height of this cloud. A photograph taken the following morning shows a steam cloud, being carried away from the camera, which by comparison with the full height of the volcano appears to be at least 3,500 meters. While the steam cloud was probably higher at the time of the main eruption than at others, it is doubtful if its burden of solid ejecta reached a greater height than the estimate just given.

Estimates ranging from 10 to 15 kilometers have been submitted, based on photographs of the electrical discharges in the cloud, the calculation involving the focal length of the camera, the size of the image and the distance from the camera to the cloud, which is assumed to be vertically above the volcano. The probable error in these estimates arises from the fact that in all cases the cloud, by its rapid lateral expansion has moved toward the photographer. The lightning streak on the surface of the cloud (the streak must be on the surface of the cloud toward the camera, otherwise it would be obscured and appear as a flash if seen at all) is always closer to the camera than the foregoing assumption makes it. Estimates based on measuring the horizontal angle from a known point to the apparent top of the cloud are obviously liable to similar error. If the lightning flash shown in Plate VII of the paper by Charles Martin was directly over the crater, then it was about 4,500 meters long and 100 meters wide.

A feature of the movement of the explosion cloud not generally observed by the people who watched it, probably because of the darkness, but abundantly indicated by study of the devastated area, was its terrific sweep downward and outward from the crater rim. The principal evidence of this movement is obtained from its effect on the vegetation on the lower slopes of the volcano, and the west shore of Lake Bombon. The heavy growth of cogon grass was flattened absolutely, and the tips point radially away from the crater. The occasional patches of scant forest, except where protected by the natural topography, were completely destroyed although not burned. Even on the

west shore of the lake, large trees were either uprooted or broken off close to the ground. These too, almost invariably fell away from the crater, and the bark was abraded from their exposed surfaces. On the island, broken ends of tree stumps and branches were literally shredded, as though exposed to the action of a powerful sand blast. This abrasive effect was undoubtedly accomplished by the sand grains in the ash or mud which the expanding cloud carried with it. Outside the central area over which this explosive expansion of the gases was felt, the eruption caused only a rain of mud, which fell gently.

This downward and outward movement is difficult of conception to those who saw the steadily rising cloud above the volcano during the recent activity. However, when it is recalled that explosions tend to act equally in all directions, downward as well as upward, and when it is remembered that the air above the crater was already heavy with condensing steam and falling mud when the main explosion occurred, it is apparent that expansion would naturally take place in the manner described. A photograph taken during the less violent activity shows the cloud spread downward over the base of the volcano. (Plate X, fig. 1.)

It is probable that at a greater distance from the crater than was attained by this outward expansion, the atmosphere moved toward the volcano, as a center of low pressure resulting from the upward rush of the cloud. Such a movement is evidenced by the sudden falling of barometers around the volcano. In Manila, an otherwise regular barograph at the Weather Bureau Observatory shows a sharp drop of 1 millimeter at the moment of the eruption. At Batangas a similar drop amounted to 2 millimeters. At both these places there was a slight wind toward the volcano after the eruption. At Talisay, the natives said that the wind first came strongly from the volcano bringing mud, then changed and blew toward the mountain. It is shown by the distribution of ejecta that the prevailing wind during the eruption came from the southwest (off the sea).

Electrical phenomena.—For an hour or more during the greatest activity the cloud above the volcano was vivid with lightning which played in streaks, often branched or forked, and ran either up or down or obliquely over the cloud. A subdued thunder, less distinct than would be expected from seeing the lightning, accompanied it. Flashes or sheets of light were also quite generally noted, and were explained by many who saw them as resulting from the combustion of inflammable gases within the cloud. It is more probable that they were merely reflections of the streak lightning from the surfaces of other parts of the cloud.

Spectacular electric displays have been prominent features of many

volcanic eruptions. Special descriptive names have been applied to this particular type of lightning.³

Its origin has been ascribed to the generation of electricity by the intense friction occurring between the individual ash particles in the moving cloud.⁴ Probably friction between ash particles and the air or friction of the vapor-laden gases of the rising cloud with the surrounding drier atmosphere, are contributing causes.

*Earthquakes.*⁵—The earthquakes accompanying the recent activity of Taal are tabulated in chronological order in a report "The Eruption of Taal Volcano, January 30, 1911" written by Father Miguel Saderra Masó, Assistant Director of the Weather Bureau. Father Masó concludes that the earth-movements were very local, that they emanated from the immediate vicinity of the volcano and that they lost intensity very rapidly as they traveled away from that center. The most violent earthquakes recorded in Manila were of intensity IV of the earthquake scale of De Rossi Forel⁶ and Father Masó thinks it probable that even in the vicinity of the volcano no shock occurred more intense than VII.⁷ Consequently, a shock of intensity III at the volcano might not be felt in Manila at all. It is beyond question that a great many more shocks really did occur near the volcano than were recorded in Manila. The local extent of the earthquake shocks suggests that the center of Taal's late activity was not at a great depth.

A curve of earthquake occurrence (Plate V) has been prepared from Father Masó's tabulation which suggests the nature of the change in earth stresses throughout the eruption. It is conceived that the first steep rise in the curve, showing many earthquakes, would correspond to a period of developing stresses due to pent-up volcanic activity; the intermediate flatter section would represent a period of relief occasioned in a measure by the opening of earth fissures, but mainly by the explosive outburst of the volcano; the subsequent sharp rise in the curve marks a period of readjustment to the relieved condition, during which vertical displacement occurred along the fissures, and subsidence took place over parts of the affected area. The final gradual flattening⁸ denotes the return of normal stability.

Damage due directly to earthquakes was slight. The towns of Taal

³ Hovey. E. O., Martinique and St. Vincent, *Bull. Am. Mus. Nat. Hist.* (1902), 16, 333.

⁴ Scrope, G. P., *Volcanoes*, London, 2. ed. (1862), 57.

⁵ The earthquakes in connection with the eruption of Taal will be the subject of a special Bulletin of the Philippine Islands Weather Bureau.

⁶ Strong enough to shake movable objects, chairs, and windows, etc.

⁷ Strong enough to overturn movable objects, shake off plastering, etc.

⁸ Minor shocks continued to occur up to February 13.

and Lemery were most shaken. In Lemery the tower of the Casaysay Church was partly demolished. (See Plate XII, fig. 1.) Masonry gateposts in the wall which surrounds the church were overturned and fell to the west. This church is directly in the line of one of the fissures and some of the damage is evidently due to the vertical displacement along it as the west side dropped. With the exception of the fissuring, which is usually connected with more intense earthquakes, the evidence in Taal and Lemery bears out Father Masó's conclusion that the strongest earthquakes did not exceed intensity VII. Numerous small landslides occurred in the steeply eroded hills of volcanic tuff to the west of Lake Bombon. The shocks cracked and displaced several old masonry walls in Talisay.

Water wave.—It has already been stated that Lake Bombon rose suddenly just after the main eruption. This wave (or series of waves close together) washed up on the lake shore through a vertical distance of 2.5 or 3 meters carrying away houses and causing loss of life in some of the *barrios*. If, as seems established, no severe earthquake occurred for some time before this wave was observed, its cause must be sought in another direction.

It will be brought out in another part of this paper that the whole of Volcano Island sank from 1 to 3 meters during the recent activity. If this subsidence took place in one quick drop, it probably caused a large wave to pass over the lake surface. However, it is inconceivable, considering its size, that the island could be moved suddenly enough, and through a sufficient distance to cause such a water wave, without also producing a very severe earthquake. Moreover, some subsidence had already occurred when Mr. Martin visited the island Sunday morning and observations indicate that there was further subsidence after the activity had become insignificant. It is probable, on the whole, that the island sank gradually, causing only minor earthquakes and very slight disturbance to the lake surface. Comparison of photographs of the crater taken on January 30 and 31, indicates the disappearance of certain portions of the margin of the active center at some time between the above dates. See Plate I, fig. 2 and Plate II, fig. 1, in the paper by Charles Martin.

The explosive rush of gases down the volcano slopes affords a possible explanation of the water wave. This blast, the strength of which is intimated by the absolute destruction it wrought not only over the whole island but on the west lake shore, moved with a considerable downward component (tending to expand equally in all directions) until the moment it reached the lake level. Responding to this downward pressure, the lake surface would be depressed, and its reaction would cause

a wave or waves. Thus, the water would have literally been blown away from the volcano to the lake shores.⁹

EJECTA.

Character.—The known ejecta from Taal in this eruption were (1) steam (probably water also), (2) sulphur dioxide, (3) angular pieces of homogeneous extrusive rock, (4) fragmental blocks of volcanic tuffs and agglomerates, and (5) volcanic mud or ash.

Steam made up practically the whole volume of the gases. The odor of sulphur dioxide was strong during the eruption and probably this gas or its oxidation product was effective in killing vegetation.¹⁰ Other gases, notably carbon dioxide, may have been present in the cloud. There was apparently no odor of hydrogen sulphide and there is no evidence of the presence of other inflammable gases.¹¹

The angular boulders thrown out ranged up to perhaps 300 kilograms in weight. The large rocks fell on the upper slopes of the volcano near the crater's rim. Andesitic specimens and others of basaltic character, neither with any appearance of recent fusion, were noted. These rocks may represent individual blocks from agglomerate phases of the tuff which apparently supplied the rest of the solid ejecta.

The blocks of tuff thrown out are identical in appearance with the bedded material of the crater walls. Some of the fragments weigh perhaps 200 kilograms. Other large pieces had broken from the impact

⁹ It is difficult to estimate the velocity of expansion of the eruption cloud at the time it reached the lake level. Generally accessible data show that a wind velocity of 100 miles (160 kilometers) per hour is sufficient to uproot large trees. Large trees were uprooted 2 kilometers inland from the west lakeshore. Since the velocity must have decreased very rapidly as the expansion progressed, it may have been as high as 200 miles (320 kilometers) per hour at the foot of the volcano. Wind moving with this velocity would exert a pressure of 200 pounds (Trautwine, John C., London, 17. ed. (1900), 321) per square foot (4 kilograms per square centimeter), sufficient actually to support a column of water 1 meter high. This estimate does not take into account the considerable inertia of the dense load of mud or ash which traveled with the wind, and which would increase its effect.

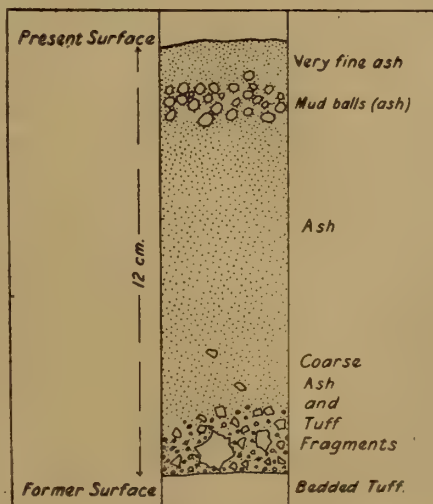
¹⁰ At Bañadero, where cool mud fell without violence to the depth of 1 centimeter, the leaves of the trees retained only a thin coating on their upper surfaces, yet within twelve hours many leaves and some fruit, such as oranges and wild fruits, had fallen, suggesting an effect of poisoning from the mud. Ultimately, all leaves and fruit in this section died. In several instances clothing, such as brown flannel shirts, white towels, etc., on which mud fell at Bañadero, was stained yellow. In San Pablo the fall of mud was very light, "like sugar sprinkled over a cake," yet garden plants were killed by it according to Mr. W. E. Crowe, supervising teacher.

¹¹ Brooks of the Bureau of Science found neither hydrogen nor carbon monoxide in the gases from a very active vent which opened in the crater before the recent eruption.

of their fall. Bedding planes could be distinguished in many fragments. Generally, these tuff and agglomerate specimens were visibly impregnated with sulphur, and often they were deliquescent from contained salts.

The finer ejecta which have been referred to as mud or ash contain a large proportion of clear, glassy fragments, some grains of glassy scoria, both light and dark in color, and a residue of larger grains forming a coarse, black sand consisting of basaltic pebbles and dark-colored mineral grains. The material would be classed readily as a fine-grained andesite tuff and is precisely similar in physical character to the finer grained tuffs forming the crater walls. Fragments intermediate in size between the large blocks and the finer ash occur at the base of the mud-fall near the crater as shown in the accompanying text figure. Possibly some dry ash fell on the volcano slopes, having been in the cloud too short a time to be affected by the steam. A sample of the fine ash taken on the upper south slope of the volcano has been analyzed chemically in the laboratory of general, inorganic and physical chemistry, Bureau of Science, and appears on page 94.

An interesting feature of the fall of the ejecta is the formation of drops or balls of mud. These were most abundantly seen on the island itself, but were observed at Talisay and Bañadero also. They range in size from large shot to hazelnuts, and when broken sometimes show concentric markings. Apparently they fell late during the activity, being found just below the surface of the deposit. These mud balls can not be classed as lapilli in the strict sense of that term, since they were built up, probably through the condensation of steam into drops of water. The accompanying vertical section of the fall of mud or ash (text figure No. 2) was taken on the southwest slope of the volcano.



TEXT FIG. No. 2.

With the exception of the small number of incandescent stones, ejecta from this eruption were apparently not much hotter than boiling water.¹² Obviously this was true of the mud which formed through the condensation of steam. The burns on the wounded were generally due to this hot

¹² Brooks found the gases issuing from an exceptionally active vent in the crater of Taal previous to this eruption to be at a temperature of only 420°.

mud.¹³ No evidence of burning, charred or scorched grass or wood, could be found, even on the island. Neither the clothes nor the hair of the victims on the island were singed. Several rocks were noted on the volcano slopes the burnt appearance of which suggested recent incandescence. Such rocks should have burned any vegetation with which they came in contact. However, in their fall they had invariably scooped out such holes or gashes that no vegetation was left close enough to have been affected.

Volcanic bombs.—A block of scoriacious andesitic lava (roughly oval, 1 meter in greatest diameter) was found on the southwest slope of the volcano about 1 kilometer from the crater rim. This is very similar to the "bread crust" bombs commonly mentioned in connection with volcanic activity. This specimen had been broken by its fall, although the resulting pieces had not dropped apart. A fragment is shown in Plate XI, fig. 2. It exhibits the characteristic surface "cracks," and in addition shows a sharply defined outer zone of much denser texture than the delicate scoriacious interior. This bomb may be a fragment of ancient lava torn from the side of the volcano throat, only the surface of which, apparently, has been fused by the recent activity.

Distribution.—Probably very few pieces of the solid ejecta larger than mere pebbles were carried farther away than the limits of the island.¹⁴ All the large blocks observed fell on the upper slopes of the volcano, although on the west side many boulders had been washed down the mountain by flows of water subsequent to the fall of solid material.

Text figure No. 1 shows the distribution of solid ejecta from Taal. Three roughly concentric areas have been outlined. The smallest one, 230 square kilometers, includes the devastated region where man and large animals were killed by the direct action of the volcano. It also limits approximately the area over which the fall of mud or ash exceeded 10 centimeters in average thickness. The next larger area is approxi-

¹³ Major Gurney, of the Philippines Constabulary, who treated a large number of wounded in the field hospital work, observed that the burns were usually of the first order. It is suggested in this connection that the abrasion of scalded surfaces due to the velocity of the flying mud, may have intensified the effect of the burns in many cases.

¹⁴ Early reports told of a *banca* (native canoe) load of people which left the *barrio* of Mapulongbato on Sunday night and was halfway across the lake toward San Nicolas when 21 out of the 26 occupants were killed by falling stones. Lieutenant Dominguez, Philippines Constabulary, states that the *banca* (which with the five survivors was washed ashore) sustained little damage other than the loss of the outriggers. There were no holes in the boat. This damage might have been done by the "water wave," the people being drowned when the *banca*, deprived of its outriggers through the breaking of the rattan lashings, upset.

mately that over which the average thickness of the fall of mud exceeded 1 centimeter. The limits of these two areas have been fixed from personal notes. Over the largest area, 1,940 square kilometers, the mud formed a noticeable continuous coating, more than 1 millimeter (approximately) in thickness; beyond this limit it was only visible by close observation. Information from people in the near-by towns has been relied upon for the extreme eastern and western limits of this area.¹⁵

The greatest fall of material within the devastated area was on the west slope of the volcano. The maximum thickness of 2 meters noted here occurred where the ash and small fragments had drifted into an old water course. However, the ridges adjacent were all but bare, and therefore an estimate of 20 to 30 centimeters for the average maximum depth of fall for this vicinity is probably reasonable.

The map showing the distribution of ejecta affords an interesting study in the position of the crater relative to the centers of the three areas outlined and in the varying direction of the longer axes of these areas. Evidently the distribution was governed by forces from two directions. The area of devastation, due solely to volcanic action, lies considerably to the west of the crater, its center is approximately 4 kilometers N. 65° W. of the latter. The center of the largest area, the limits of which were determined mainly by the wind, lies northeast of the crater. To the southwest the limits of the three areas are very close together, showing that in this direction the material traveled only as far as the expanding cloud carried it. It is concluded that the prevailing wind encountered by the eruption cloud, especially in its upper

¹⁵ At Santa Cruz, La Laguna, according to Dr. R. A. Brown, a slight fall of mud began just fifteen minutes after he was awakened by the noise of the eruption. The mud was barely noticeable the next morning.

At Marigondon, Cavite, the mud "was as the dust which gathers on the show cases of the open shops after the street sweepers have passed along an unsprinkled street." (Personal letter from municipal president.)

The mud could be distinguished from Cabuyao to Lipa on the Batangas extension of the Manila and Dagupan Railroad.

No mud fell in Cuenca, Taal, Tuy or Nasugbu, Batangas Province.

Dust fell in Manila six to eight hours after the eruption, and was visible on furniture and other smooth surfaces the next morning.

Comparing these areas to similar areas from the eruption of Mont Peleé in May, 1902 (see Hovey, E. O., *Am. Journ. Sci.* (1902), 14, 320), it develops that Taal devastated more than twice the area that Mont Peleé did although the eruption was probably of much lesser magnitude. The ashes from Peleé spread over an area probably ten times as great as those from Taal. The crater of Mont Peleé is 1,280 meters above sea level, while Taal in places is as low as 100 meters. Thus the eruption from Mont Peleé had much more room for downward expansion, and the same energy at the crater threw its ejecta much higher in the air than in the case of Taal.

portion. blew approximately N. 55° E. and that the force of the eruption was directed to the west or slightly northwest.¹⁶

The concentration of the force of the volcanic action in a certain direction may be attributed most reasonably to the contour of the crater rim which (Plate III) is lowest and most distant from the active part of the crater in its western and northwestern portion. However, it will be noted that the southwest side of the rim is comparatively high and close to the active crater, yet destruction was complete and extensive to the southwest. A suggested explanation of the greater devastation to one side of the crater, lies in the assumption that the throat of the volcano is not vertical but dips to the east, thus directing its ejecta to the west. Such an assumption is unnecessary and is probably not warranted by the evidence which appears to support it.

EARTH FISSURES.

Description and trend.—The system of fissures (See Plate I) which formed during this eruption is significant of the relation of Taal Volcano to the general structure of the region. This subject has been one of considerable interest to geologists who have studied this area. Centeno¹⁷ placed Taal on an approximately north and south line with Mount Arayat in the central valley of Luzon north of Manila. Adams¹⁸ thinks it probable that Mount Arayat is on the same structural line as Taal and argues that the general trend of structure in southwestern Luzon is to the northwest. However, he suggests the possibility of a line through Balayan Bay, Taal Volcano, and Laguna de Bay, and sees a possible elevated fault-block in the high ridge north of Lake Bombon and west of such a line.

The trend of the recent fissuring indicates a line of weakness passing through Taal Volcano and bearing about N. 30° E. This trend extended beyond the limits of the system and runs closely parallel to the east coast of Luzon and the length of Palawan, passing through Laguna de Bay and Balayan Bay. (See index map, Plate II.) The earthquakes were strongest in Taal and Talisay, along this line. The alignment of craters on Volcano Island conforms well with such a trend as do also

" At Subig, southwest of the crater where the mud fell 10 centimeters deep, a considerable portion of the town was swept by the water wave resulting from the explosion. This area was left quite clean of mud, while up to its limits the general depth prevailed. At Talisay and Bañadero, northeast of the crater, and slightly more distant, the low ground washed by the water wave showed the same depth of mud as the adjacent upland. Apparently the whole fall of mud due entirely to the explosion at Subig had occurred before the water wave finally receded and it was carried away by it, while at Talisay and Bañadero, whither the mud was carried by the wind, the fall occurred after the wave had receded, and covered the area washed by it.

¹⁷ Estudio Geológico del volcan Taal, Madrid, Tello (1885).

¹⁸ *This Journal*, Sec. A (1910), 5, 101.

the outline features of both island and lake. No recent fissure could be traced across the island itself, a fact scarcely explained by the greater fall of ash. If the fissures noted owe their trend entirely to movement radial from the crater their location is still significant, since careful search discovered no other radial fissures around the lake.

The fissures are vertical, remarkably regular, and show only a vertical (no lateral) displacement. Where the displacement exceeds about 20 centimeters there is a sharp break and resulting scarp, otherwise only a gentle roll along the line of trend is evident. Generally speaking, the maximum displacement is along the central portion of the fissure, decreasing gradually to each end. It should be noted that displacement did not take place completely at the time the fissures appeared. It increased perceptibly for several days, during which earthquakes were frequent, after the opening of the fissures.

The two most prominent fissures occur along the bases of the walls of bedded tuff which form the main terraces of the Pancipit River Valley. Their vertical displacements vary up to about 3 meters, and their scarps face each other across the valley. The intermediate fissures have displacements not exceeding 1.5 meters (averaging about 0.8 meter). The whole system bears an evident relation to the existing structure. The intermediate fissures occur on relatively high ground (see text figure No. 3), around which the Pancipit River makes a wide detour to the west. The ground surface slopes to the east, the strata (tuff) dip slightly to the east and the fissure scarps generally face the east. In the town of Lemery, a minor fissure leaves the general trend of the system to follow the contact between the tuff and recent alluvial for a short distance.



TEXT FIG. NO. 3.

There is a noticeable tendency to maintain the displacement along the trend of the system by alternate parallel fissures. One fissure begins where another ends; thus the system presents a staggered arrangement.¹⁹

Along the main fissure in the town of Lemery the displacement was accomplished by dropping of the lower side, while the upper remained stationary. This is evidenced by the fact that the sea now comes inland farther than formerly on one side of the fissure, and remains at its old

¹⁹ See Hobbs, William Herbert, *Earthquakes*, New York (1907), 72.

level on the other. Whether or not this was the usual occurrence is not certain, but judging from the positions of the two main fissures and the fact that the displacement generally took place after the earth stresses had apparently been relieved, this instance would be typical.

If this system of fissures is along a plane of extensive former faulting, as has been suggested, then earthquakes which affect southwestern Luzon, independent of volcanic action, as well as those due directly to eruptions from Taal, probably would be most violent along its trend. It would mark both a volcano-tectonic and a seismo-tectonic line. The towns of Lemery and Taal, situated as they are on this line, would especially be menaced by earthquakes. As pointed out by Hobbs²⁰ in his study of Italian earthquakes, the suggestion of moving towns on such lines should seriously be considered.

Mud cones or craterlets.—Little violence, other than sharp earthquakes, seems to have accompanied the formation of these fissures. Natives say that a rush of gas occurred when the large one along the west side of the Pancipit Valley opened. Several people noticed clouds of dust shoot up along other fissures of the system. At Sinaysian, a *barrio* near the seacoast on the large fissure just mentioned, a number of gushing springs were noted soon after it opened. These springs are not exactly on the fissure, but occur irregularly over a small marshy area in the adjacent alluvial formation. On February 18, there were about twenty still very active, gas escaping into the air with considerable noise, and mud and water gushing up to a height of about one-half meter. The loose ground around the larger vents was perceptibly agitated. Most of the springs had built up mud cones, perfect craterlets of fragmental tuff, perhaps 2 meters in diameter and 30 centimeters high. Both gas and water were at ordinary temperature.

Samples were taken and subsequently examined in the laboratory of physical and inorganic chemistry of the Bureau of Science. The water proved to be ordinary ground water not unusual in any respect. It probably bears no relation to the gas which escapes with it, and is interesting only as evidence of the disturbance of established ground-water flow by the recent fissuring.

The sample of gas showed 97 per cent carbon dioxide and a residue of atmospheric air, probably from contamination in taking the sample. The evolution of large volumes of carbon dioxide at this distance (18 kilometers) from the volcano is remarkable. Abella²¹ visited the *barrio* of Sinaysian in 1893 and examined the celebrated spring of San Raymundo, which at that time had a flow of 151 meters per hour. He observed the escape of gas near by. This spring has not flowed for some

²⁰ Seismic Geol., *Ibid* (1907), 225.

²¹ Estudio descriptivo de algunos Manantiales minerales de Filipinas. Inspección General de Minas de Filipinas, Manila (1893).

years, according to the natives, and the former escape of gas was unknown to them. Abella analyzed the water from San Raymundo, the flow of which he related to Taal Volcano, and found the following main mineral constituents:

Constituent.	Grams per liter.
Free carbonic acid	0.36
Calcium bicarbonate	0.58
Magnesium bicarbonate	0.13
Sodium sulphate	0.11
Sodium chloride	0.31
Ferrous arsenate	Trace.

The temperature of the spring was 32°. The trace of arsenic compounds is interesting because of their frequent association with mineral veins.

In speculating as to the probable origin of this carbon dioxide, an observation made by Adams²² while studying this region, claims attention. "In making an excursion south of Lemery along the beach to Point Ligpo, a limestone was found included by basalt and evidently metamorphosed by contact with the igneous rocks into a very dense stone. A peculiarity of this limestone * * * was the presence of small cavities, or druses, lined with clear quartz crystals." Point Ligpo is only a few kilometers from Lemery and it is not improbable that similar basalt flows or intrusions underlie the adjacent valley where these fissures formed. Local coral reefs may have been built during the intermittent deposition of volcanic tuff and now be covered by later beds. In any case inclusions of limestone, metamorphosed and subjected to the action of mineral-bearing waters, would probably evolve carbon dioxide and such action along the plane of recent fissuring would account for the escape of carbon dioxide.

CHANGES IN ELEVATION.

The subsidence of the lower Pancipit Valley (evidently the upper part of the valley did not subside) has been mentioned. The extent of this subsidence can not be given exactly but was probably not greater than 3 meters at any place. About 1 kilometer of macadamized road west of Lemery is now covered at high tide with perhaps 50 centimeters of water.

It is estimated that this road was formerly from 1 to 2 meters above high tide. There is an apparent subsidence of a few centimeters on the west side of the fissure which opened in Talisay.

The most striking subsidence noted was that of Volcano Island itself. Here it was general around the whole perimeter, amounting to more than 3 meters in places. Longos Point was cut in two and the resulting small island is separated by water a meter in depth from the main island.

²² *This Journal*, Sec. A (1910), 5, 100.

Bignay Point will probably similarly be changed before the work of cutting down the new shore line is finished. These peninsulas were at the northeast end of the island. This part sank about 3 meters, judging from submerged tree stumps. A new beach is building over an old sugar-cane field on the southeast shore of the island. Cogon grass and stumps of trees with their roots intact could be seen all around the island beneath about 1 meter of water.

The relative level of the lake is changed. It is lower by about 1 meter on its south shore line and is lower by a smaller amount on its north shore. The water in the upper part of the Pancipit River stands at a lower level now than formerly. The subsidence of Volcano Island would tend to lower the level of the lake on its shores but apparently not to such an extent as has occurred. It is not improbable that the whole shore line of the lake has risen slightly, reacting from the subsidence of the island at its center.

CHANGES IN THE CRATER.

Outwardly, Taal Volcano was little changed by its recent eruption. The absence of vegetation and the smooth drifted surface of the ash covering which is almost white in the sunlight, give the island an appearance of a vast snow heap. The crater rim is unbroken and save for minor fissures and cracks is intact. Sulphur is burning rather vigorously part way down its outside slope on the north side of the crater. This had never been noted before the eruption.

The interior of the crater has been transformed. Plate III, showing maps of the crater before and since the recent activity, and Plate IV, showing cross sections made from these maps, indicate what change has occurred. The well-known Green Lake and Yellow Lake, which were small bodies of water, one of which (Yellow Lake) was quite shallow, referred to in descriptions of Taal since earliest historic times, are gone. In the position of the former Green Lake there is a new one, the water of which appears milky-white, due to suspended solid matter. The level of this lake was on February 17 approximately 70 meters below that of the sea.²³ Green Lake had stood 5 meters above sea level.

²³ The map of the changed crater was made by reading vertical and horizontal angles from known points with a Verschoyle pocket transit. The same instrument was used for mapping the fissure system, distances being paced. In mapping the crater, elevations were determined by reading vertical angles from seven prominent points on the crater rim to two points on the edge of the crater lake (located from the horizontal angles). Readings from the rim to the lake were checked by reading the same angles from the lake rim. The elevations on the rim were determined accurately by a recent Bureau of Lands survey, and were changed only slightly, if at all, by this eruption. The results were averaged and the figure given should not be in error more than 10 per cent. A superior aneroid barometer was read at each elevation and the angle determinations were thus checked.

Two streams of hot water, the combined flow of which was estimated at 100 to 150 cubic meters per minute, were pouring into the lake. These streams came out of the crater walls about 50 meters above the lake level, seeping from just over a layer of fine-grained, impervious, bedded tuff. On the west shore of the lake a conical rock 50 to 70 meters in diameter rose to a height of 115 meters above the lake level. The upper 50 meters of this natural obelisk appeared to be bedded tuff, but the lower portion is massive basalt. A week later, the streams pouring into the crater lake had increased both in volume and in number, and the lake itself had risen apparently about 5 meters.

The center of the recent activity seems to have been at a point near the south end of the former Green Lake, or between Green Lake and the 1904 crater, although the vicinity of the "Gas Vent," shown on the map of the old crater, is still very active. Vents from which steam escapes violently, and small craters gushing mud and hot water, are found at various places over the new crater floor. The present lake is boiling at a number of places and great volumes of steam arise from its surface. There is no evidence of a general subsidence in the crater. No breaks or fissures appear near the shelf outside of which the old floor is intact. There are no faulted or tilted blocks which might indicate that the old floor had dropped. On the other hand, the new floor, exposed by the streams flowing across it, is composed of dense, basaltic material, hard and flowlike in appearance, certainly in place. It is probable that the change in the level of the crater floor was due to removal of material from the crater, not to the collapse or subsidence of the old floor.

An approximation of the volume of solid material ejected from Taal Volcano during the late activity is readily obtained by calculation from the data given in connection with the distribution of the ejecta. Disregarding irregularities in the ground surface, the volume of the solid represented by plotting sections, from the average depths shown, across the area covered, is 70 to 80 million cubic meters.

Calculating in a similar manner the volume between the old and the new floor lines in the crater according to areas and cross sections obtained from Plates III and IV, the approximate figure of 45 million cubic meters is obtained for the volume removed above the level of the new lake.

Examination of the crater walls below the old floor line reveals that a large portion of the material removed was rather dense, bedded tuff. If this material were ground up to a fine sand or ash and spread out in a thin layer, as mud, it would probably occupy at least one and one-half times its former volume, or about 68 million cubic meters.

While these figures are approximate and represent at best only the order of magnitude of the volumes sought, yet it is evident that enough

surface material was removed from the crater, allowing only a shallow depth for the new lake, to make up the volume of the solid ejecta. The appearance of the ejected mud, its low temperature, and its irregular character, all bear out the conclusion that it consists almost entirely of the material removed from the surface.²⁴ The few incandescent stones may have come from slightly lower down in the volcanic throat, but even these were probably originally thrown out by former volcanic activity and were only worked over recently.

It is improbable that Taal has ejected original molten material within historic time, although among the last of the geologically recent beds in its crater wall there is a thin layer of basaltic lapilli. It is true that accounts of the eruption of 1754 mention floating pumice and scoria on Lake Bombon, but patches of scoria were observed on the lake surface after the recent eruption during which no scoria were thrown out. These patches of floating pumice in the recent activity resulted from the action of the water wave on the bed of lapilli near the ground surface of the island and the lake shore. The scoria of the former eruption may have been due to a similar action.

If no part of the solid ejecta of the recent eruption was newly cooled lava (either as scoria or ash), there seems to the writer to be a difficulty in explaining this explosive outburst by the more commonly accepted theory of explosive volcanic action; i. e., as the sudden escape of steam and other absorbed vapors from molten lava. It is incredible that gases should escape from a liquid magma with such violence and not bring with them fragments of that magma either as ash or scoria.

Although hot and heavily mineralized,²⁵ the water which is flowing into the new crater probably is seepage from Lake Bombon through the crater walls. Since Lake Bombon stands a few meters above sea level, the new crater lake will probably rise in time to about sea level. It is not apparent that this larger body of water in the crater will have any material effect on the activity of the volcano. It will probably tend to muffle the minor surface violence, by yielding more readily to pressure and dissipating more rapidly the heat that reaches the upper part of the volcanic throat, than the rigid, heat-insulating earth which it replaced.

The large column of rock or "obelisk" which appeared in the crater of Taal Volcano during this eruption is at present a striking object (it

²⁴ A fresh sample of the mud was sent to Mr. H. D. Gibbs, chief of the division of organic chemistry of this Bureau, to be tested for radio-activity, with the idea that if the material were of deep-seated origin it might be radio-active. The test, made within three days after the eruption, showed no radio-activity.

²⁵ A sample of the water from one of the streams was taken, and has been analyzed. See the article by Dr. Alvin J. Cox in this number.

will be partly concealed as the new lake rises). Its position and height indicate that its top formed a part of the high ground shown on the map of the old crater just west of Green Lake. Being more resistant, it withstood the force of the eruption which tore out the looser material around it, except on the side which the obelisk itself protected. This specimen consequently is an entirely different type from the spine which pushed up from the crater of Mont Peleé during the year succeeding the eruption of May, 1902. The latter with the fragmental cone which it surmounted, actually grew about 900 meters high, apparently being pushed up bodily from below.²⁶ The new obelisk in the crater of Taal resembles an old volcanic neck or plug, and such an origin might be assigned to it from the evidence in hand.

LOSS OF LIFE.

The official report submitted by Colonel W. S. Rivers, Assistant Director of the Bureau of Constabulary, who conducted the relief work for the Taal sufferers, estimates the human dead at 1,335. There were recovered and buried 732 bodies. Of these, 106 were found on Volcano Island and 618 along the west shore of Lake Bombon between the *barrios* of Subig and Bayangan, inclusive.

The magnitude of this eruption of Taal has been both exaggerated and belittled. Consequently it is of interest to compare it briefly with a great volcanic eruption. In May, 1902, Mont Peleé devastated an area of 83 square kilometers (32 square miles), killed 30,000 people, and spread ashes (in one direction at least) over a radius of 160 kilometers (more than 100 miles). A large proportion of the ash which it threw out was incandescent, burning and scorching vegetation and wooden structures. The crater of Mont Peleé is about 1,280 meters (4,200 feet) high.

Recently Taal exerted a devastating violence over an area of approximately 230 square kilometers (part of this area was lake surface; the land surface devastated was about 98 square kilometers). The greatest distance from the volcano at which an appreciable depth of ash fell is about 52 kilometers, and the number of people killed is 1,335 (official estimate). Thus Taal devastated a greater area than Peleé, yet it spread its ash over an area probably less than one-tenth as large. This apparent inconsistency is readily explained by the difference in elevation of the respective craters. The barrio of Gulod is approximately the same distance from the crater of Taal as St. Vincent (where most of the losses of life occurred) was from the crater of Mont Peleé, and, like St. Vincent, was in the path of greatest violence of the eruption. In Gulod, 116

²⁶ Hovey, E. O.; New Cone and Obelisk of Mont Peleé, *Bull. Geol. Soc. Am.* (1904), 15, 558.

people were killed out of a total population of 120, and this proportion would probably have been the same if 26,000 people had been living in Gulod, as there were in St. Vincent.

RÉSUMÉ.

First, the eruption of Taal Volcano which occurred January 30, 1911, was probably the most severe, considering the number of lives lost and the damage caused, the area of the region affected and the changes wrought in the volcano itself, which has occurred in historic times in the Philippines. It was of the explosive type, the violent activity continuing only a few hours, and the attendant phenomena being typical of this class of eruption.

Second, the principal ejecta from Taal Volcano during this eruption were steam and volcanic ash or mud. Some incandescent stones were thrown out. The volcanic ash or mud probably resulted from the attrition, by mutual friction within the cloud, of bedded tuff which was torn from the floor of the crater. Little, if any, ejecta came (recently) from a great depth. The mud or ash spread over an area of 2,000 square kilometers.

Third, the violent action of the eruption was more effective to the west of the volcano, due largely to the contour of the crater rim.

Fourth, a system of earth fissures opened during the eruption, the trend of which indicate a tectonic line passing through Balayan Bay, Taal Volcano, along the probable fault block, the eastern scarp of which is marked by Mount Gonzales, and through Laguna de Bay. Towns along this line near the volcano suffered most from the earthquakes accompanying the eruption, and are most liable to damage from earthquakes during possible future eruptions.

Fifth, general subsidence of the ground level took place over a considerable area after this eruption. The island on which the volcano is located subsided and the surrounding lake changed its level. The crater was materially deepened through the removal of material from its floor.

Sixth, the most significant thing about this eruption is the probability that all its solid ejecta were surface material and the apparent absence even at the seat of volcanic activity of molten lava, which most theories of vulcanism require to account for this type of eruption.

Seventh, the chief agent of destruction and the main cause of death resulting from the eruption was the explosive expansion of the escaping steam, which was violent owing to its movement and suffocating owing to its heat, its burden of mud, and a content of sulphur dioxide.

It is remarkable to be able to sum up perfectly the phenomena of

this eruption of Taal in the exact words applied by Hovey ²⁷ to the eruptions of La Soufrière and Mont Pelée in 1902.

"It is evident that there was a blast or a series of blasts of hurricane violence from the crater * * * as a feature of the eruptions * * *. The overturned trees constitute the principal evidence * * *. They all point away from the crater except for slight modifications due to local topography. The blast extended radially in all directions from the crater suggesting the explanation that some great volume of steam, rising from the throat of the volcano could not find room for expansion upward on account of the column of steam and ashes which had preceded it and the ashes falling therefrom and that it expanded with explosive violence horizontally and downward, following the configuration of the mountain."

²⁷ Eruptions of 1902 of La Soufrière, St. Vincent, and Mont Pelée, Martinique. *Am. Journ. Sci.* (1902), 14, 326.

ILLUSTRATIONS.²⁸

PLATE I.

Relief map of Taal Volcano. (From division of mines, Bureau of Science.)

PLATE II.

Map of the vicinity of Taal Volcano showing fissures caused by the eruption of January 30, 1911.

PLATE III.

Maps of the crater of Taal Volcano showing changes wrought by the eruption of January 30, 1911.

FIG. 1. Crater prior to January 30. (Taken from topographic map by S. B. Coleman, Bureau of Lands.)

2. Sketch map of Taal Volcano made February 17, 1911. Dotted line shows contour of crater lake on April 9, as observed by Doctor Smith.

PLATE IV.

Superimposed cross sections of crater before and after recent activity. Prepared from Plate III.

PLATE V.

Curves of earthquake occurrence as recorded in Manila during recent activity of Taal Volcano, showing apparent relief of earth stresses at the time of the main eruption. Prepared from data furnished by Father Miguel Saderra Masó, Assistant Director of the Weather Bureau.

PLATE VI.

Taal Volcano in eruption, January 29, 1911.

PLATE VII.

Eruption cloud as it appeared from Bañadero, January 30, 1911.

PLATE VIII.

Crater of Taal Volcano before recent eruption. Looking west.

PLATE IX.

Crater of Taal Volcano as it appeared on May 5, 1911. Taken from same point as Plate VIII.

²⁸ Photographs by Charles Martin, photographer, Bureau of Science, Manila, P. I.

PLATE X.

- FIG. 1. Eruption during the afternoon of January 30, 1911, showing cloud sweeping down the volcano slopes.
2. Mud and stones in eruption, January 30, 1911.

PLATE XI.

- FIG. 1. Showing the effect of the mud blast on trees at Gulod, 8 kilometers from the crater. Natural size.
2. Fragment of "bread crust" bomb, showing re-fused appearance of the crust and original scoriaceous texture of interior. The bomb from which this fragment came measured about 1 meter in greatest diameter, and fell about 1 kilometer away from the crater rim.

PLATE XII.

- FIG. 1. Casaysay Church in town of Taal damaged by earthquakes. Looking northeast.
2. General view near *barrio* of Bayungan showing destruction wrought. Looking north.

PLATE XIII.

- FIG. 1. Fissure in town of Lemery. Looking east.
2. Fissure near the *barrio* of San Nicolas. Looking south.

PLATE XIV.

- FIG. 1. View inside the crater, February 26, 1911, showing the obelisk-like mass uncovered by recent activity.
2. Stream flowing into new crater lake, from seepage through crater walls. February 26, 1911.

TEXT FIGURES.

- No. 1. Map of a portion of southwestern Luzon showing area covered by mud from the eruption of Taal Volcano, January 30, 1911. Three roughly concentric areas are shown.
- Outside the largest area the mud-fall was less than about 1 millimeter.
- Outside the intermediate area the mud-fall was less than about 1 centimeter.
- Outside the smallest area the mud-fall was less than about 10 centimeters.
2. Vertical section of the fall of mud on the southwest slope of Taal Volcano.
3. Diagrammatic section across the Pansipit River Valley showing position of earth fissures.



PLATE I.







FIG. 1

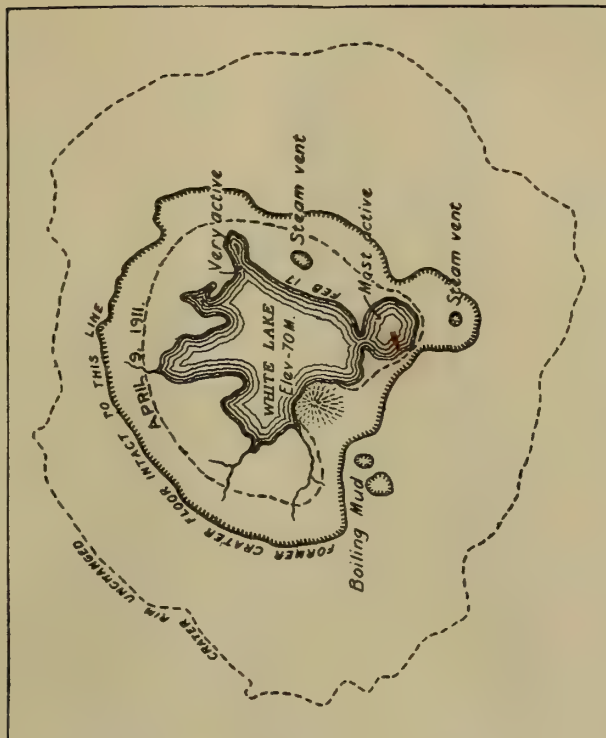


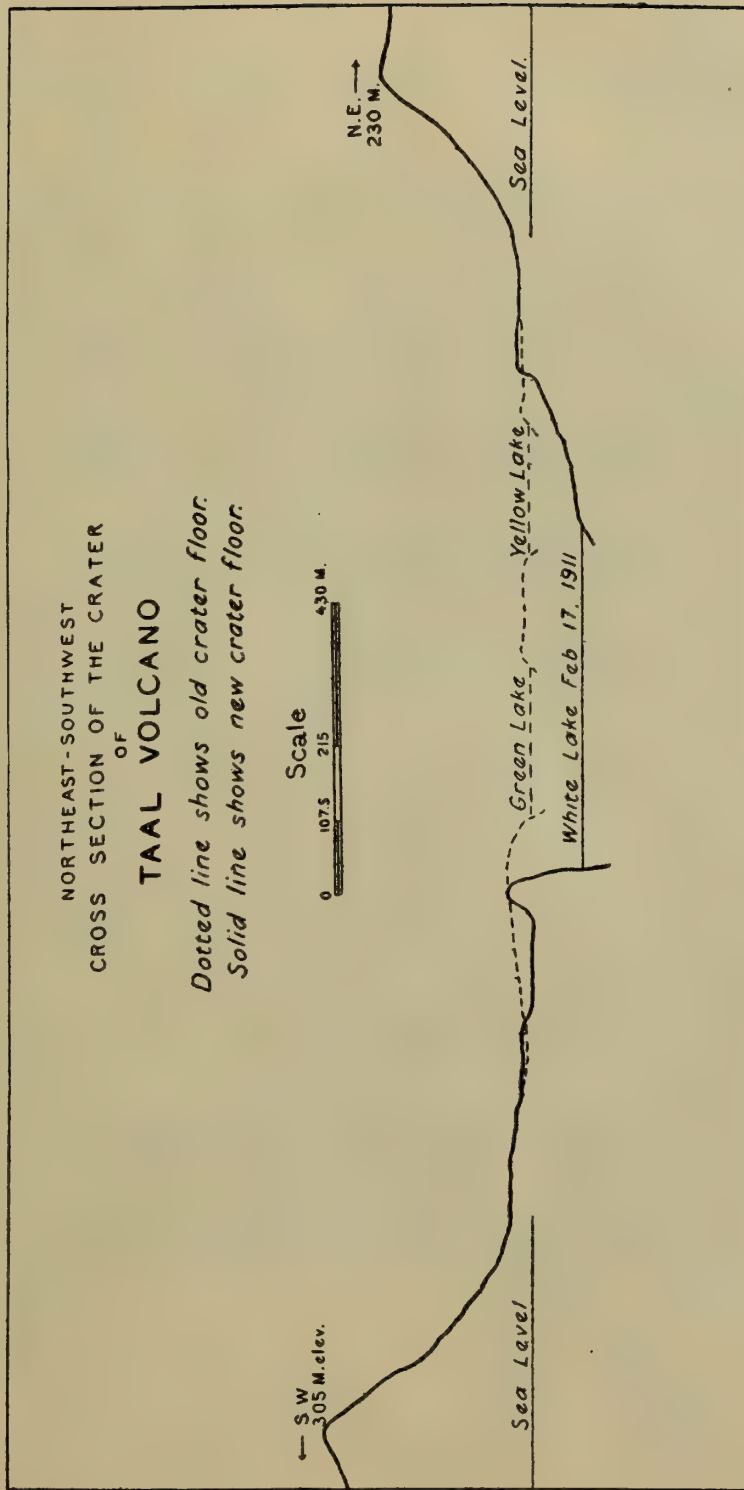
FIG. 2.



SCALE
500 1000 M.

PLATE III.





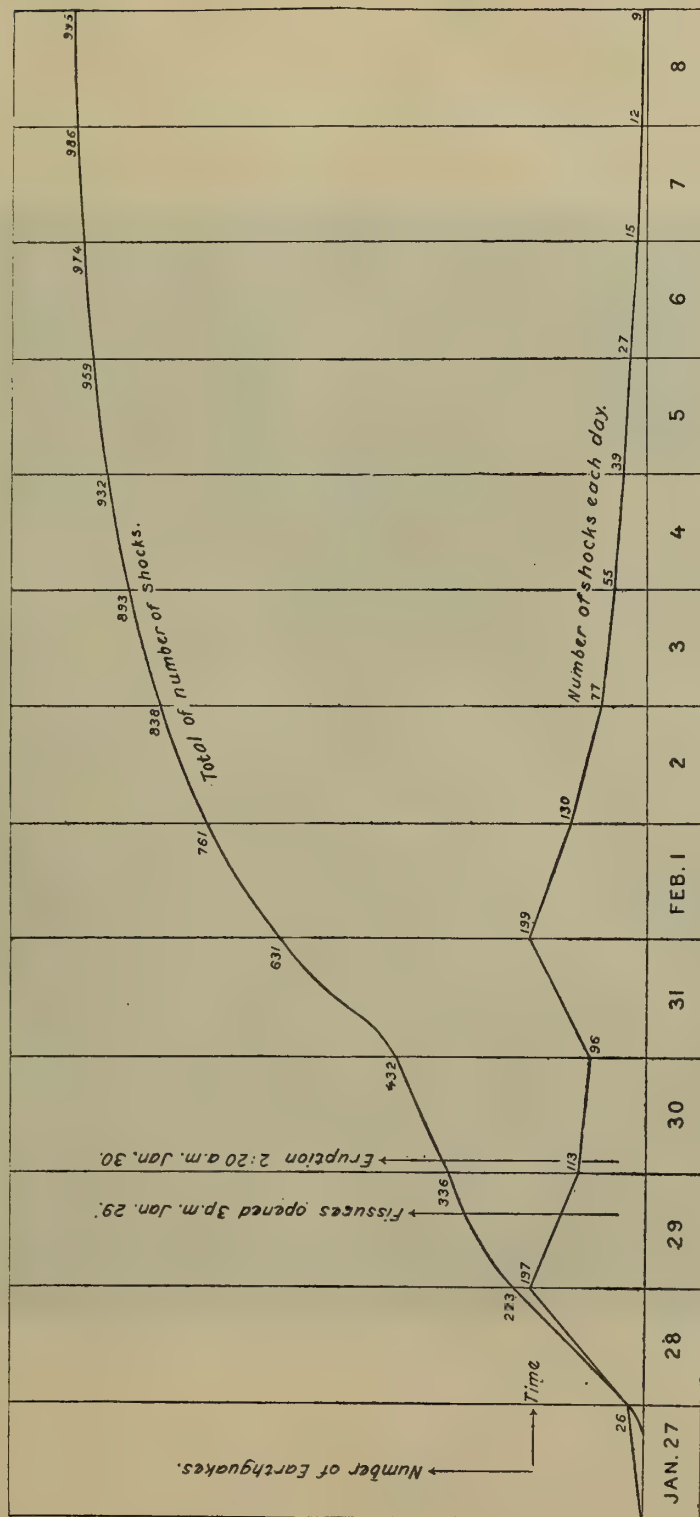


PLATE V.

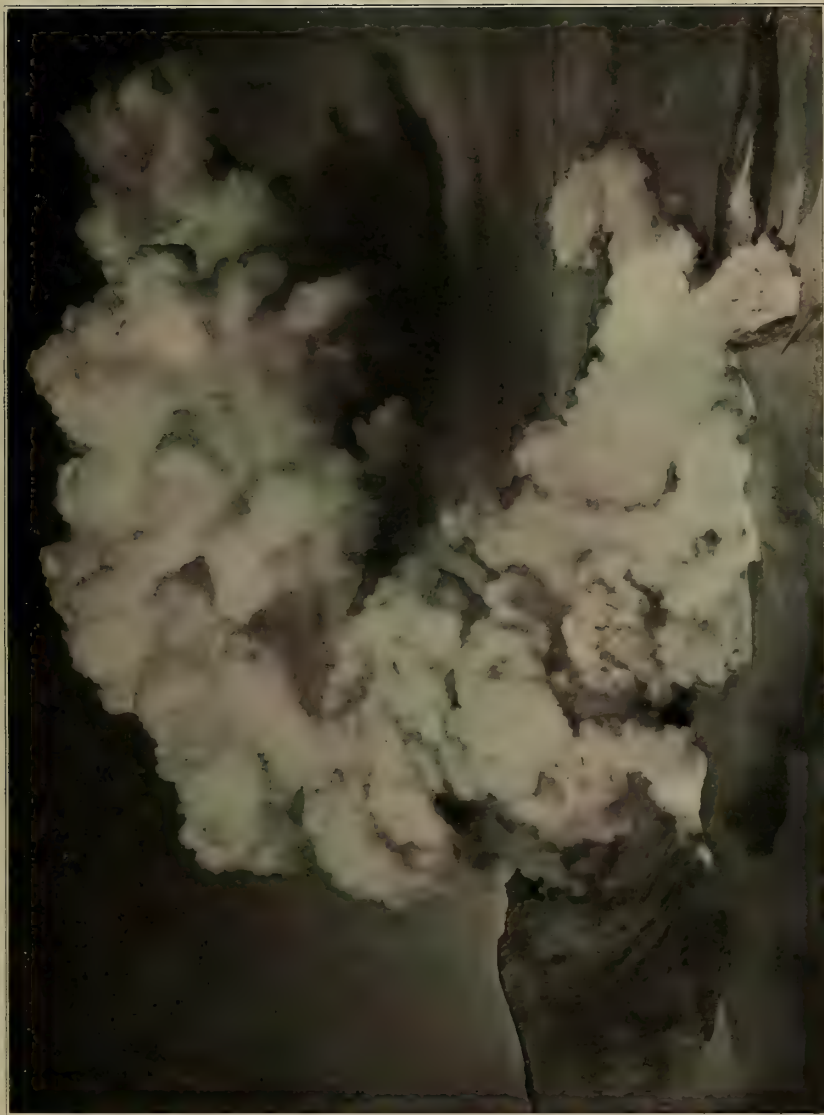


PLATE VI.



PLATE VII.

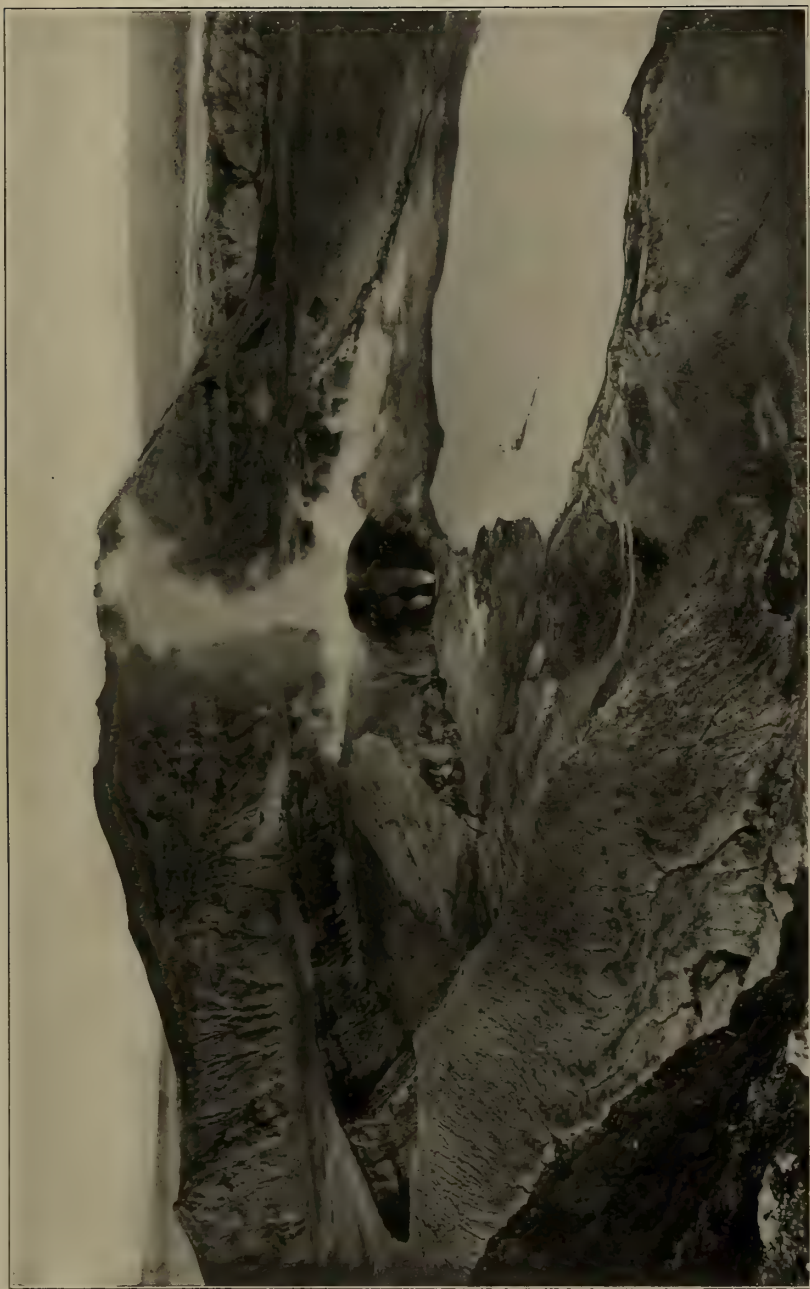


PLATE VIII.



PLATE IX.

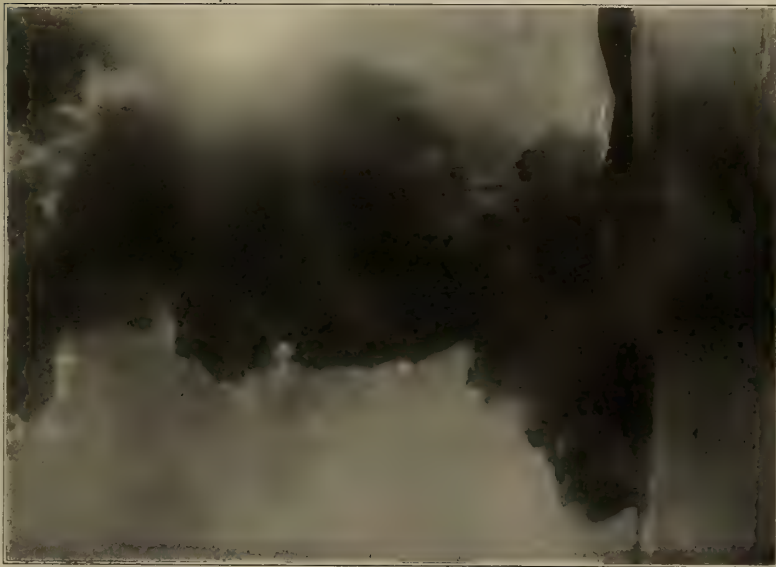


FIG. 1.



FIG. 2.

PLATE X.



FIG. 1.



FIG. 2.

PLATE XI.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.

PLATE XIV.

OBSERVATIONS ON THE RECENT ERUPTION OF TAAL VOLCANO.

By CHARLES MARTIN.

(From the Photographic Laboratory, Bureau of Science, Manila, P. I.)

The inhabitants of Manila experienced several earthquakes on Friday, January 27, 1911, and these became decidedly strong on Saturday morning. Notice was received by the Bureau of Science on Saturday, January 28, that the Volcano of Taal, situated some 50 kilometers south of Manila, was in a state of eruption.

I had, in previous years, secured series of photographs illustrating the condition of the crater, and as the invaluable set of views taken by Mr. Dean C. Worcester was at the disposal of the Government, I at once started for the volcano in order to continue these comparative studies. I reached Bombon (Taal) Lake at 8 o'clock on the evening of the same day and passed the night of January 28 and 29, on the shore of the lake. At 11 o'clock at night there was a spectacular eruption, with flashes of lightning in the cloud of mud thrown up; deep rumblings were plainly heard from Bañadero.

I was on the edge of the crater at 8 o'clock on the morning of January 29. The volcano was then very active. This is well shown by the photograph of the great masses of clouds. (See Plate I, fig. 1.) There had been a fall of mud varying from 5 to 10 centimeters in depth on the edges of the highest ridges of the crater. The southern and southeastern slopes were not affected by this because of the direction of the wind, although a ravine carried liquified mud down to the lake on the southern side.

I returned to Tanauan, the nearest point on the railroad to the volcano, the same afternoon. At 1 o'clock on the morning of January 30 a vast column of mud was ejected from the volcano; lightning was seen playing in the clouds and loud thunder was heard in Tanauan; but no rumblings from the crater. Mud began to fall in Tanauan fifteen to twenty minutes afterward. At first this consisted of fine, damp particles; afterward it was dry, and continued to fall in the latter condition for twenty minutes more.

The sky became absolutely clear shortly before 2 o'clock and at 2.20

or 2.30 two tremendous explosions, not more than one-third or one-half of a second apart, were heard that sounded as if a piece of the heaviest artillery had been fired on the outskirts of Tanauan itself. The immense column of mud thrown up is estimated to have reached a height of not less than 4 kilometers. The column kept on rising, but soon the winds spread it out over the country, leaving us in total darkness. Wet mud began to fall in Tanauan about twelve minutes after the explosions and kept on falling for not less than half an hour until it covered the ground 1 millimeter in depth.

The next morning I decided to return to the volcano. I reached Bañadero at 8.30 on the morning of January 30 and observed that the mud had killed banana trees and other delicate vegetation about 5 kilometers inland. Three weeks later, on going over the same route, I noted that everything was sprouting again on the Bañadero road, which was about the last point to the northeastward from the island to suffer from the fall of volcanic mud. Arriving at Bañadero I found the launch and the house boat grounded by the alleged tidal wave of the previous night; this wave was not over 1.2 meters high.

At 1 o'clock in the afternoon we started for the island with the repaired launch, reaching the top of the volcano at about 3 o'clock. The crater was full of steam and very active. Mud and stones were thrown up continually toward the western side.

It was my opinion at the time that no animal life on the island could have withstood the eruption; Taal Island was devastated, not a blade of grass escaping; trees 15 centimeters in diameter were broken, leaving stumps 0.3 to 0.5 of a meter high; the ends of these stumps were shredded like whisk brooms by the fall of sand and small stones driven by the force of the eruption (See Plate III, fig. 1); a large stone weighing not less than 275 kilograms was projected clear on top of the highest ridge.¹

A rock was found by Mr. Pratt with its surface fused, giving it the appearance known as bread crust, but I have never seen either fire or red-hot stones ejected. Possibly the heat was sufficient to fuse rock, but, of course, from Tanauan I would not have been able to determine this question. While I was on the crater's rim, the most active cone was not throwing up anything that could possibly be called "fiery" even with a strong imagination; the eruption consisted mainly of mud.

The trees on the island were lying in directions radiating from the crater. The fall of the mud, although sufficient to break all the branches could not have broken the trunks 15 to 25 centimeters from the ground; such results were caused by the terrific explosions.

The whole island has subsided from 2.5 to 3 meters. That this is

¹ A photograph of the latter appears in the article by Wallace E. Pratt in this number of the *Journal*.

the case is shown by the trees which formerly were on high ground and now are found in water a meter or more in depth. (See Plate VI.)

We left at 3.45 in the afternoon on our way back to Bañadero. At 4 o'clock the island was covered by an erupting cloud of mud which swept down the slopes of the crater, soon enveloping the whole island. The latter was continually shaken by earthquakes while we remained on it. At the time we were on Taal, natives were rescuing the few survivors, some 12 or 13, all badly wounded, from the barrio of Pirapiraso 5 kilometers to the northward. They were taken to Talisay, where well-meaning relatives attempted to stuff these poor people with meats, dry crackers, and strong coffee.

My assistant joined me on Tuesday morning with additional photographic plates and Messrs. Eddingfield and Pratt, geologists from the division of mines, also came to Bañadero with the intention of taking observations. We went directly to the first *barrio*² on the northeastern side called Pirapiraso. There we met some natives who were taking away the bodies of dead relatives. They informed us concerning the rescuing of wounded survivors the previous day and of their removal to Talisay; a number of dead people were found at this place. (See Plate IV.) We visited the remaining *barrios* on the island, but found them completely buried under the mud. The launch left us on the north side of the island. Mr. Pratt and I with our baggage took a rowboat to reach our destination, a good hour's rowing distance from the spot, while the launch proceeded to Talisay.

Mr. Pratt, and I camped in the island on Tuesday. The ground very frequently was shaken by earthquakes. We went to the crater's edge at 3.30 in the afternoon January 31; the activity had lessened since Monday. (See Plate II, fig. 1.) The next morning we went up again and observed that the activity was further reduced, although the frequency of earthquakes was the same. We attempted to work around to the south, but because the fall of mud was so deep and the crust would not support our weight so early in the morning, we were compelled to return. However, we went far enough to enable Mr. Pratt to take his triangulations and to confirm our opinion of the total devastation of the island. We next rowed to the *barrio* of Pirapiraso and found corpses in an advanced state of putrefaction.

During the first week of February, I was directed to accompany Mr. Pratt on a trip overland from Lemery to Tanauan. A number of fissures as well as the damage to buildings in Lemery were observed and photographed.³ (See Plate V, fig. 1.) We had an opportunity fully

² *Barrio*, a small village, administered by a larger town which may be at some distance from it.

³ For other photographs see the article by Mr. Pratt in this number of the *Journal*.

to observe and appreciate the extent of the destruction caused by the eruption on the mainland by visiting the several *barrios*, some of which, toward the western side of the island, were wiped out.

Even on the mainland, I observed that the bark of trees toward the volcano was lacerated and in some cases on exposed plateaus it was entirely eroded by the particles of mud and fine sand blown against it by the force of the eruption. Therefore, the wounds found on rescued natives may not have been caused by burns.

If the force of the blast of mud and sand was such as to wear the bark off of trees and even to shred the wood, the effects on human beings can readily be surmised. Neither Mr. Pratt nor I found signs of burns on the dead bodies, nor indications of fire on the island. The fused surface of a rock, thrown out, was the only thing found that indicated the great heat which, of course, was present somewhere in the depths.

ILLUSTRATIONS.⁴

PLATE I.

- FIG. 1. Part of the crater showing location of old Yellow Lake which has disappeared. Note the numerous small craterlets with steam.
2. Crater showing great activity, January 30, 1911.

PLATE II.

- FIG. 1. View of crater on January 31, 1911.
2. Banana trees destroyed by eruption, Talisay, Batangas.

PLATE III.

- FIG. 1. A tree 15 centimeters in diameter broken by the force of the eruption and shredded like a whisk broom by the mud driven by the force of the eruption.
2. General view of the *barrio* of Pirapiraso, Volcano Island, after the eruption.

PLATE IV.

- FIG. 1. Wrecked houses in the *barrio* of Gulod, 8 kilometers from the crater.
2. A man and woman killed by the eruption, *barrio* of Pirapiraso.

PLATE V.

- FIG. 1. Casaysay Church steeple damaged by earthquakes, January 29 and 30, 1911. Taal, Batangas.
2. *Barrio* of Subig, Batangas, destroyed by the eruption.

PLATE VI.

View near the northeast corner of Volcano Island showing trees partly submerged in Lake Bombon through the sinking of the island.

PLATE VII.

Lightning in the eruption of mud at 2.30 a. m. January 30, 1911. Photograph from Tanauan.

⁴Photographs by Charles Martin, photographer, Bureau of Science, Manila, P. I.



FIG. 1.

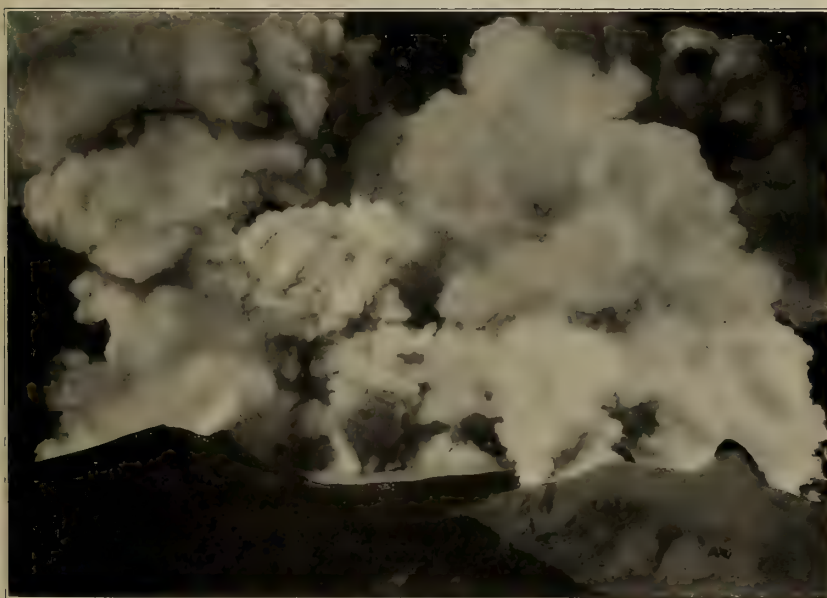


FIG. 2.

PLATE I.

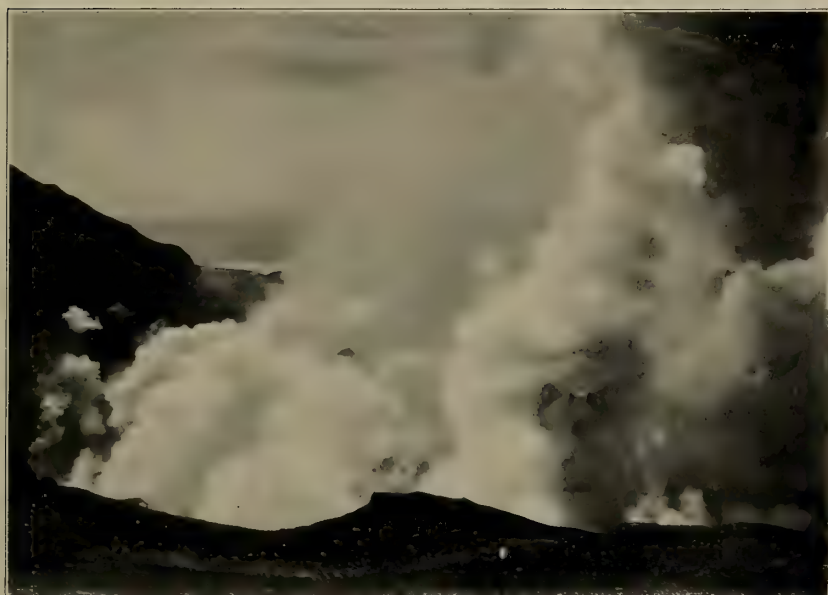


FIG. 1.



FIG. 2.

PLATE II.



FIG. 1.



FIG. 2.



FIG. 1.



FIG. 2.

PLATE IV.



FIG. 1.



FIG. 2.

PLATE V.



PLATE VI.

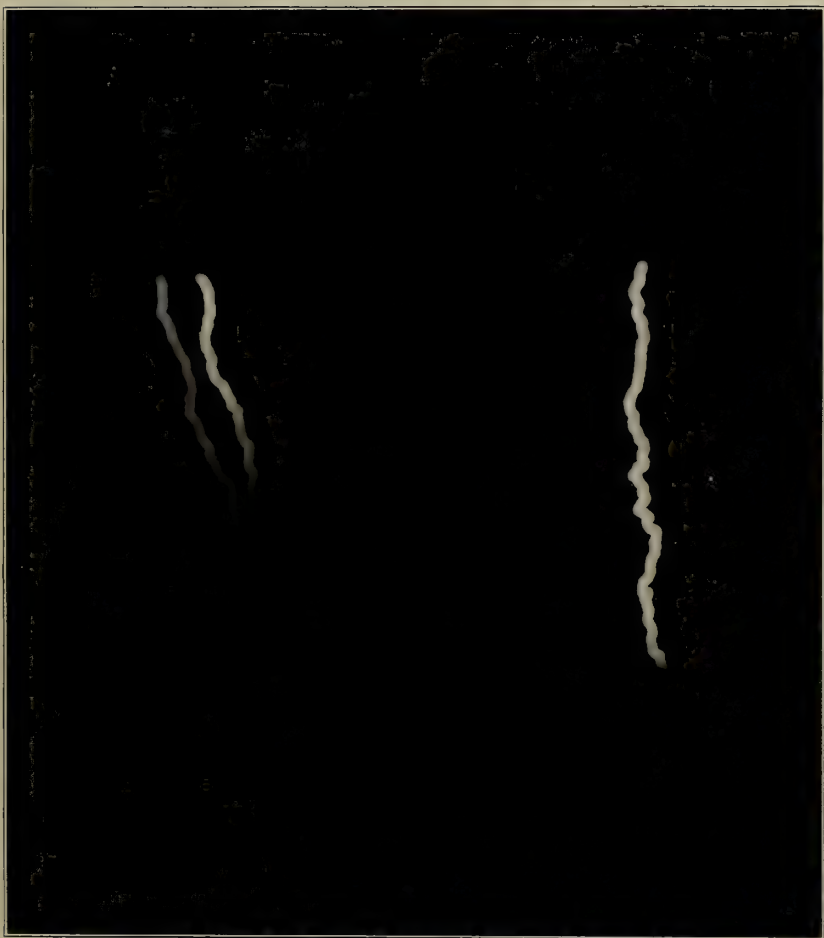


PLATE VII.

THE COMPOSITION OF THE FINE EJECTA AND A FEW OTHER INORGANIC FACTORS OF TAAL VOLCANO.

By ALVIN J. COX.

(*From the Laboratory of General, Inorganic and Physical Chemistry, Bureau of
Science, Manila, P. I.*)

In the recent activity of Taal Volcano which began on January 27 and gradually increased in intensity until the explosion which took place about 2 o'clock on the morning of January 30, 1911, mud or "ash" was thrown out and spread in different depths over an area of more than 2,000 square kilometers.

Two samples of these ejecta were collected soon after the eruption, air-dried, and analyzed. The results are given in Table I, and in parallel columns I have tabulated some of my former analyses of volcanic tuff from various sources, to show the similarity. The first column of Table I gives the analysis of a sample of the finest "ash" collected on the upper southern slope of the volcano; the second that of the same sample calculated as free from readily soluble matter and moisture; the third represents the area on the mainland over which the mud was distributed to a thickness of about 1 centimeter and beyond the devastated region (See Map, fig. 1, in the article by Wallace E. Pratt); the fourth column gives the analysis of the same sample calculated as free from readily soluble matter and moisture; the fifth, sixth, seventh, and eighth give figures for tuff from Manila, Guadalupe, and Majaijai respectively.

TABLE I.—Analyses of the finer ejecta from Taal Volcano and of samples of volcanic tuff.

[Numbers give percentages.]

Constituent.	Finest ash from upper southern slope of Taal.		Ejecta from area where mud was 1 cm. deep.		Tuff from—			
	As collected.	Calculated as free from readily soluble mat- ter and moisture.	As collected.	Calculated as free from readily soluble mat- ter and moisture.	Manila.	Guadalupe.		Majajai.
						1906.	1908.	
I ^a .	II ^b .	III ^a .	IV ^b .	V.	VI.	VII.	VIII.	
NOT READILY SOLUBLE IN WATER.								
Silica (SiO ₂) -----	45.76	50.79	44.63	50.94	56.84	56.55	59.27	57.26
Alumina (Al ₂ O ₃) -----	14.57	16.17	13.33	15.22	18.46	22.34	17.06	16.95
Ferric oxide (Fe ₂ O ₃) -----	2.89	3.20	3.24	3.70	0.75	1.87	2.16	-----
Ferrous oxide (FeO) -----	5.20	5.77	5.04	5.76	2.51	-----	2.61	7.55
Lime (CaO) -----	6.94	7.70	6.25	7.13	4.78	4.74	3.37	3.56
Magnesia (MgO) -----	2.59	2.87	2.70	3.08	1.59	2.36	1.52	1.10
Soda (Na ₂ O) -----	None.	-----	None.	-----	4.12	2.38	.49	1.64
Potash (K ₂ O) -----	None.	-----	None.	-----	2.72	2.84	3.63	1.86
Loss on ignition -----	^d 1.18	^d 1.31	^d 1.19	^d 1.36	6.95	4.86	6.42	7.65
Water (H ₂ O) (below 105–110°) -	5.03	None.	6.35	None.	1.76	2.51	1.34	1.43
Titanic oxide (TiO ₂) -----	1.20	1.33	1.14	1.30	(^e)	(^e)	0.83	0.91
Manganese oxide (Mn ₃ O ₄) -----	Trace.	Trace.	Trace.	Trace.	Trace.	-----	Trace.	0.23
Sulphuric anhydride (SO ₃) -----	9.49	10.53	10.11	11.54	-----	-----	-----	-----
Free sulphur (S) -----	0.45	0.50	0.37	0.42	-----	-----	-----	-----
Phosphoric anhydride (P ₂ O ₅) -	0.05	0.06	0.03	0.03	-----	-----	-----	-----
READILY SOLUBLE IN WATER. ^f								
Silica (SiO ₂) -----	0.82	-----	0.95	-----	-----	-----	-----	-----
Iron and aluminium oxides (R ₂ O ₃) -----	0.01	-----	Trace.	-----	-----	-----	-----	-----
Lime (CaO) -----	0.16	-----	0.32	-----	-----	-----	-----	-----
Magnesia (MgO) -----	None.	-----	None.	-----	-----	-----	-----	-----
Soda (Na ₂ O) -----	1.51	-----	2.03	-----	-----	-----	-----	-----
Potash (K ₂ O) -----	1.34	-----	1.25	-----	-----	-----	-----	-----
Manganese oxide (Mn ₃ O ₄) -----	Trace.	-----	Trace.	-----	-----	-----	-----	-----
Sulphuric anhydride (SO ₃) -----	0.30	-----	0.60	-----	-----	-----	-----	-----
Phosphoric anhydride (P ₂ O ₅) -	None.	-----	None.	-----	-----	-----	-----	-----
Chlorine (Cl) -----	0.74	-----	0.95	-----	-----	-----	-----	-----
Total -----	100.23	100.23	100.48	100.48	100.48	100.44	100.70	100.14

^a Analyzed mostly by Mr. T. Dar Juan.^b These numbers are approximately comparable to Columns V to VIII, although it is quite probable that in time the sulphates would be leached out or hydrolysed and give a closer relationship to the tuff which is found in various places in the Island of Luzon than that shown by these analyses.^c Includes titanic oxide (TiO₂).^d Actual loss on ignition—(moisture + sulphuric anhydride + $\frac{1}{2}$ sulphur).^e Included in alumina (Al₂O₃).^f Three months after collection.

The physical composition of the distributed material is of interest and importance. According to the geologists' records no pebbles were carried beyond the limits of the island. Mechanical analyses of such material as is available are given in Table II.

TABLE II.—*Mechanical analysis of ejecta from Taal Volcano.*

[The samples analyzed were air-dried. The numbers give percentages.]

Sample No.	Moisture.	Soluble matter.	Size of grains in millimeters.							Total.
			>0.5.	0.5-0.25.	0.25-0.1.	0.1-0.05.	0.05-0.01.	0.01-0.002.	<0.002.	
a ¹	5.03	5.07	27.10	7.54	27.42	27.26	0.15	0.47	0.00	100.04
b ²	6.35	6.21	7.15	5.75	48.51	24.72	0.38	0.41	0.00	99.48

^a This is a sample of the finest "ash" collected on the upper southern slope of the volcano. The detritus on a 2-millimeter sieve was 9.1 per cent and in a 20-gram sample consisted of 70 particles the largest of which was 6 millimeters in diameter.

^b This sample represents that from the area over which the mud was distributed to a thickness of about 1 centimeter and beyond the devastated region. (See Map, fig. 1, in the paper by Wallace E. Pratt.) There was no detritus on a 2-millimeter sieve.

While a considerable amount of coarse material fell on the island, the mud that was carried to a distance was comparatively finely divided, in this respect not greatly unlike road dust. The mud was cool wherever its fall was observed, and it descended in the manner of rain, without violence. Leaves retained only a thin coating on their upper surfaces, yet within a few hours many of them had fallen. Ordinary road dust may fall on plants to any thickness without serious injury. Certain crops are reported as stunted by the volcano's action at the College of Agriculture farm where the fall of mud was very slight. Garden plants were injured in many places where only a very small quantity of mud fell.

There is nothing in the above analyses which indicates that the mud is injurious to plants. However, it is probable that the chemical analyses do not accurately represent its composition as it fell, for no heterogenous substance is in a constant state of equilibrium, but rather in a changing state of equilibrium according to known laws.

There are at least two possible sources of the injury to the plants. One of these is the presence of sulphuric acid. In the regions near the volcano the odor of sulphur dioxide was pronounced during the eruption. A mixture of this gas and water vapor under the oxidizing influence of the electric discharge may have produced sulphuric acid in an amount sufficient to be injurious. There was unquestionably a large amount of free acid in the vapors from another source during the eruption, for analyses made by Dr. R. F. Bacon,¹ formerly of the Bureau of

¹ *This Journal* (1906), 1, 434; *Sec. A* (1907), 2, 118.

Science, show that the water in the crater lakes contained large amounts of easily hydrolyzed salts, those of aluminium and iron predominated, and that these were in equilibrium with free acid varying from 1.28 to 2.08 normal. Calculated as hydrochloric acid, the above numbers are equivalent to 4.65 and 7.57 per cent respectively, and as sulphuric acid the equivalents are 6.14 and 10.28 per cent respectively. All of these lakes disappeared at the time of the eruption. In either event the free acid would in turn react with the other compounds in the mud to form harmless salts of the acids which are shown by analysis to be present, but probably not until injury to the vegetation had taken place.

I have made a number of analyses of the deposits covering the walls of the crater lakes and have always found them to consist largely of salts of the rock forming metals with no free acids, which shows that the acid in the water thrown on the rocks as spray from the boiling lakes reacts with the rocks themselves. Therefore, one would not expect to find free acid by a chemical analysis, even though it was known to exist in the recent ejecta from the volcano.

A sample of water taken since the eruption from near the mouth of the north stream flowing into the crater gives corroborative data and indicates that another acid lake is being formed. Its analysis, together with that of water from the larger lake surrounding the volcano, is given in Table III.

TABLE III.—*Water analyses.*
[Figures indicate parts per million.]

Constituent.	Water flowing into the new crater lake. ^a	Lake Bombon. ^b
Color	Milky.	.....
Acidity	0.0069 N.	.....
Silica (SiO ₂)	710.8	31.5
Iron (Fe)	172.0	} 4.2
Aluminium (Al)	26.1	
Manganese (Mn)	79.9	.....
Calcium (Ca)	556.8	53.4
Magnesium (Mg)	909.3	49.4
Potassium (K)	237.4	.....
Sodium (Na)	2,584.3	456.3
Lithium (Li)	None.	.....
Sulphuric ions (SO ₄)	2,732.0	191.3
Phosphoric ions (PO ₄)	None.	.....
Metaboric ions (BO ₂)	Small.	.....
Arsenic ions (AsO ₄)	Small.	.....
Chlorine (Cl)	6,024.3	720
Bromine (Br)	Trace.	.....
Iodine (I)	None.	.....

^a Temperature 70°. If the stream of which this is a sample has any connection with Lake Bombon, the water dissolves so many and such quantities of salts in passing through the crater wall as no longer to be recognizable. Analyzed by V. Q. Gana.

^b Analyzed by F. A. Thanisch (1905).

A second cause of damage to the plants may exist in the large quantities of salts of iron which are often popularly called sulphur. Bacon and others writing of the volcano have noted the great extent to which the rocks are colored by a deposition of that particular iron salt which gives them a red or yellow color. These deposits, which are largely soluble salts of iron, occurred all over the crater island and were unquestionably distributed with the mud shower. The injury to vegetation may be partly traceable to them.² However, it was not to be anticipated that any large quantity of soluble iron salts would be found by the time the sample arrived at the laboratory.

² These salts give free acid by hydrolysis when in solution.

X

THE ALCOHOL INDUSTRY OF THE PHILIPPINE ISLANDS.¹

PART I.

A STUDY OF SOME PALMS OF COMMERCIAL IMPORTANCE WITH
SPECIAL REFERENCE TO THE SAPS AND THEIR USES.

By H. D. GIBBS.

(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

CONTENTS.

INTRODUCTION.

THE NIPA PALM.

THE COCONUT PALM.

THE BURI PALM.

THE SUGAR PALM.

THE OCCURRENCE OF MANNITOL IN PALM SAPS.

INTRODUCTION.

Prior to the passage of the present Internal Revenue Law² there was no way of arriving at even an approximate estimate of the amount of alcoholic beverages manufactured and consumed in the Philippine Islands for the reason that the law repealed by the present Act imposed a tax on the capacity of stills rather than upon their production. It was confidently asserted by distillers and others that the annual normal con-

¹This article is concluded in the next issue of *This Journal*, Sec. A (1911), 6, No. 3.

²Philippine Commission Act No. 1189 was made effective August 1, 1904. From August 1, 1904, to April 30, 1905, crude spirits were taxed at the rate of 10 centavos per proof liter if intended for industrial purposes, 20 centavos, if intended for consumption as beverages, and 30 centavos, if rectified and sold as manufactured liquor. These provisions of the law were amended by Act No. 1338, effective May 1, 1905, which fixed the tax on crude and rectified spirits and manufactured liquors at the same rate, 20 centavos per proof liter. Act No. 1940 increased the tax on distilled spirits from 20 to 25 centavos per proof liter effective after January 1, 1910.

sumption was 42,000,000 to 50,000,000 proof liters.³ However, the Government investigations prove this amount to be about 10,000,000 proof liters. Since the passage of the Act, August 1, 1904, accurate figures⁴ are obtainable, showing the manufacture and consumption of distilled liquors and beer. Table I shows the growth of the industry, the revenue derived therefrom, and estimates of the per capita consumption.

It is realized that any estimates of the per capita consumption of alcoholic beverages in the Philippines will be very misleading. The only census of the population was taken in 1903 and now, seven years later, it is difficult to make statements on the subject. At that time the population was given as 7,635,426 and this figure is used in the calculation of the values given in Table I.

The imports, which are insignificant, are mostly consumed by the Caucasians.

TABLE I.—*Distilled liquors and malt beverages manufactured in the Philippine Islands since the passage of the present Internal Revenue Law, the taxes collected upon them and estimates of the per capita consumption.*

Fiscal year.	Distilled spirits.		Beer manufactured by the one brewery in the Islands.		Consumption per capita in liters.	
	Quantities in proof liters.	Tax collected, amount in pesos.	Quantities in liters.	Tax collected, amount in pesos.	Distilled spirits.	Beer manufactured in the Islands.
1905 ^a ..	3,757,191	855,706.22	3,307,400	^b 132,296.04	0.49	0.43
1906---	6,461,949	1,303,573.04	3,028,959	121,158.40	0.84	0.39
1907---	8,295,884	1,681,419.00	3,059,747	122,390.60	1.09	0.40
1908---	8,657,925	1,729,757.16	3,434,749	137,390.00	1.13	0.45
1909---	9,532,537	1,899,043.35	^c 3,636,499	145,460.00	1.25	0.48
1910---	10,584,124	2,269,160.70	^d 3,771,021	153,480.00	1.36	0.49

^a 11 months. The present Internal Revenue Law did not go into effect until August 1, 1904.

^b Tax rate, 4 centavos per liter.

^c 17,228 liters exported to foreign countries.

^d 1,650 liters exported to foreign countries.

These estimates of the per capita consumption of alcoholic beverages in the Philippine Archipelago seem very small when compared with the available data of other countries.

³ Daniel T. Brown, *Manila Daily Bull.* (1907), No. 17, Nov. 3.

⁴ See Table 3, pages 102 and 103, for distilled beverages, and the distribution of the industry.

TABLE II.⁵—*Consumption per capita of alcoholic beverages in various countries of the world.*

[Quantities in liters.]

Country.	Malt liquors.	Wine.	Distilled spirits.
United States.....	65.4	1.89	5.29
Germany.....	106.5	7.07	*77.1
France.....	27.97	130.0	9.45
Great Britain.....	134.9	1.47	5.29
Russia.....	3.89	6.4	4.5
Belgium.....	210.5	4.5	5.29
Italy.....	7.94	121.7	1.28
Austria-Hungary.....	43.8	9.4	9.8
Sweden.....	31.7	0.64	7.56

^a The figure undoubtedly includes alcohol used in the arts.

However, it must be borne in mind that the Philippine figures refer entirely to alcohol consumed as beverages, while much of that used in other countries is in the industries, and the Philippine estimates do not include a large quantity of alcoholic beverages made from the various palm saps, sugar, sugar refuse, sugar cane, rice and other grains. These are manufactured without distillation, usually on a small scale by families, in almost every community of the Islands. In some districts many of the natives have one or more palm trees standing in their yards, from which they gather *tuba* for their own consumption and for the purpose of peddling among their neighbors. These fermented drinks contain from 4 to 16 per cent of alcohol.

Ninety-three per cent of the total amount of alcohol and alcoholic beverages produced in the Philippine Islands during the last fiscal year, was distilled from the saps exuding from palm trees. Over 90,000,000 liters of sap were distilled at 68 distilleries. Nine million seven hundred thousand proof ⁶ liters of alcoholic beverages were produced. All was consumed locally and almost all by the native population.

The industry is constantly increasing, not only as a revenue producer to the Government, but also in the importance of its commercial and ethical aspects. Its status, since the enactment of the present internal-revenue laws, is shown in the following table.

⁵ Statistics taken from The World Almanac for 1908.

⁶ The proof spirit referred to throughout this article is that fixed by section 3249 of the Revised Statutes of the United States which defines proof spirit as containing one-half its volume of alcohol of a density 0.7939 at 60° F. This differs from the British proof spirit which is defined by Act of Parliament to be a liquid of such density that, at 51° F., 13 volumes shall weigh the same as 12 volumes of water at the same temperature. The British proof spirit has a density of 0.91984 at 60° F., and contains 49.24 per cent alcohol by weight.

TABLE III.—Showing by provinces the quantity of distilled spirits in proof liters removed from distilleries, tax paid, and material from which produced, during the past six fiscal years, also showing quantity of distilled spirits exported and quantity removed for industrial purposes without payment of tax during same period.*

Provinces.	Fiscal year 1905.				Fiscal year 1906.			
	Nipa.	Coco.	Sugar. ^a	Total.	Nipa.	Coco.	Sugar. ^a	Total.
Albay		99,299		99,299		83,041		83,041
Ambos Camarines		70,320		70,320		81,017		81,017
Antique						19		19
Bataan	6,608			6,608	3,122			3,122
Batangas	1,957			1,957	1,357			1,357
Bulacan	459,963			459,963	1,136,142			1,136,142
Cagayan	54,329			54,329	183,475			183,475
Capiz	13,736			13,736	19,442			19,442
Cavite		1,081		1,081				
Cebu		2,345		2,345		6,255		6,255
Ilocos Sur			150,604	150,604			152,660	152,660
Iloilo		69,166		69,166		52,371		52,371
Laguna		174,441		174,441		116,020		116,020
Manila	1,484,465			1,484,465	2,985,312			2,985,312
Moro		2,106		2,106		2,204		2,204
Nueva Ecija			2,306	2,306				
Nueva Vizcaya								
Pampanga		63,857	363,173	426,530			535,148	642,894
Pangasinan		569,574		569,574		758,262		758,262
Rizal		18,392		18,392				
Romblon		9,552		9,552		1,999		1,999
Samar		10,609		10,609		12,709		12,709
Surigao		21,577		21,577		57,798		57,798
Tarlac			60,498	60,498			108,053	108,053
Tayabas		12,149	34,046	46,195		14,085	39,471	53,556
Zambales		1,543		1,543		4,241		4,241
Total tax paid	2,701,968	478,642	576,581	3,757,191	5,285,895	380,193	795,861	6,461,949
Export								
Removed for industrial purposes								
Grand total				3,757,191				6,461,949
Provinces.	Fiscal year 1907.				Fiscal year 1908.			
	Nipa.	Coco.	Sugar. ^a	Total.	Nipa.	Coco.	Sugar. ^a	Total.
Albay		77,323		77,323		111,837		111,837
Ambos Camarines		89,865		89,865		126,135		126,135
Antique								
Bataan	15,638			15,638				
Batangas	1,249			1,249				
Bulacan	1,442,269			1,442,269	1,147,709			1,147,709
Cagayan	71,994			71,994	28,722			28,722
Capiz	54,616			54,616	106,715			106,715
Cavite								
Cebu		11,324		11,324		7,023		7,023
Ilocos Sur			127,420	127,420			123,591	123,591
Iloilo		24,959		24,959		3,825		3,825
Laguna		49,970		49,970		124,520		124,520
Manila	4,903,366			4,903,366	5,262,117			5,262,117

* The data tabulated under the head of sugar, include sugar refuse, molasses 99 per cent, and grain 1 per cent, approximately.

TABLE III.—Showing quantity of distilled spirits by provinces, etc.—Continued.

Provinces.	Fiscal year 1907.				Fiscal year 1908.			
	Nipa.	Coco.	Sugar. ^a	Total.	Nipa.	Coco.	Sugar. ^a	Total.
Moro	1,112			1,112				
Nueva Ecija								
Nueva Vizcaya						407		407
Pampanga	113,157		628,201	741,358	104,613		555,651	660,264
Pangasinan	422,750			422,750	682,830			682,830
Rizal								
Romblon								
Samar	7,824			7,824	143			143
Surigao	27,287			27,287				
Tarlac			112,885	112,885			75,252	75,252
Tayabas	28,550	80,005		108,555	51,612	144,631		196,243
Zambales	1,656			1,656				
Total tax paid	7,091,468	333,446	868,506	8,293,420	7,384,461	518,378	754,494	8,657,333
Export				2,464				592
Removed for industrial purposes								
Grand total				8,295,884				8,657,925
	Fiscal year 1909.				Fiscal year 1910.			
	Nipa.	Coco.	Sugar. ^a	Total.	Nipa.	Coco.	Sugar. ^a	Total.
Albay		105,531		105,531		116,801		116,801
Ambos Camarines		166,730		166,730		175,505		175,505
Antique								
Bataan								
Batangas								
Bulacan	964,445			964,445	906,737			906,737
Cagayan	1,032			1,032				
Capiz	170,285			170,285	153,668			153,668
Cavite								
Cebú		2,945		2,945				
Ilocos Sur			134,161	134,161			138,700	138,700
Iloilo								
Laguna		259,267		259,267		236,412		236,412
Manila	6,122,894		48,690	6,171,584	7,242,910		54,860	7,297,770
Moro								
Nueva Ecija								
Nueva Vizcaya								
Pampanga	81,225		512,418	593,643	71,918		457,680	529,598
Pangasinan	591,532			591,532	561,518			561,518
Rizal								
Romblon								
Samar	3,627			3,627	26,584			26,584
Surigao								
Tarlac			49,516	49,516			21,036	21,036
Tayabas	55,117	154,455		209,572	59,988	168,105		228,093
Zambales								
Total tax paid	7,990,157	688,928	744,785	9,423,870	9,023,323	696,823	672,276	10,392,422
Export				81,995				8,020
Removed for industrial purposes				26,672				183,682
Grand total				9,532,537				10,584,124

^a The data tabulated under the head of sugar, include sugar refuse, molasses 99 per cent, and grain 1 per cent, approximately.

About 22 different beverages are manufactured from the rectified alcohol. For the greater part, they are imitations of well-known brands. The most popular of these, anisette, anisado, gin, *vino de coco*, and *vino de nipa*, vary between 10 and 55 per cent in alcoholic content.

In addition to this large amount of palm sap of which we have accurate record, due to the supervision of the Bureau of Internal Revenue, a vast volume of fermented saps of various palms is consumed without distillation. Since the internal-revenue laws place no tax upon beverages which are not distilled (except beer), no estimates of this amount can be attempted. Judging from the observations of all who have come in contact with the question, the consumption of undistilled palm saps must be very large.

The production of alcohol from palm saps is, at this time, developed only to a small fraction of its possibilities. There are vast areas of palms admirably adapted to the industry, which are accessible and, as yet, untouched by commercial exploitation.

The comparative figures as to cost of production of alcohol from various sources are as follows:

TABLE IV.—*The cost in dollars, United States currency, of the various kinds of raw materials required to produce alcohol.⁷*

Source.	Cost of the raw material required to produce one liter.	
	100 proof.	180 proof.
Sugar beets at 4.75 to 5.00 per ton	0.032	0.058
Sorghum stalks at 3. per ton	0.032	0.059
Sugar cane 3. to 3.25 per ton	0.028	0.050
Beet molasses at 15. per ton .....	.028-.029	.050-.053
Cane molasses 0.12 per gallon ^a	0.032	0.059
Jerusalem artichoke 5. per ton	0.027	0.048
Cassava at 5. per ton	0.019	0.034
Potatoes at 4. per ton for culls	0.021	0.037
Sweet potatoes 8. per ton	0.031	0.056
Barley at 0.65 per bushel of 48 pounds	0.041	0.074
Maize at 0.70 per bushel of 56 pounds	0.037	0.066
Oats at 0.35 per bushel of 32 pounds	0.046	0.082
Rye at 0.80 per bushel of 56 pounds	0.051	0.092
Nipa at 0.00389 per liter equivalent to 6.5 per cent alcohol	0.015	0.027
Coco at 0.005 per liter equivalent to 6.5 per cent alcohol	0.0384	0.069
Coco at 0.0062, 6.07 per cent ^b alcohol	0.0488	0.088

^a Deerr, Hawaiian Planter's Monthly (1910), 28, 295, states that the Hawaiian molasses as a source of alcohol and as fertilizer has a value of about \$0.083 per gallon exclusive of freight and interest. The cost of alcohol from this source is higher than the figures given in the table.

^b Actual case of one distillery.

⁷ The data concerning the nipa and coconut palms are compiled from my own investigations, the other data are taken from *Bull. U. S. Dept. Agr. Bur. Chem.* (1910), No. 130.

It will be seen from the above table that the sap of the nipa palm is the cheapest source of alcohol in the world, namely, 0.027 dollar per liter of 180 proof, or 90 per cent alcohol, estimating the raw material as delivered at the distillery, with cassava⁸ second at 0.034 dollar. The whole story, moreover, is not told by these figures. The palm saps in the ordinary process of gathering and transporting to the distillery ferment with great ease and rapidity. Therefore, in less than twenty hours when the fermentation is complete, the liquor is ready to be pumped into the stills. This factor gives to these saps a considerable advantage over other raw materials which have to be prepared for fermentation and distillation at the distillery.

As a matter of fact, there is one distillery which is now producing 93 per cent alcohol (186 proof) at a cost of 0.10 peso Philippine currency (0.05 dollar United States currency) per liter with their plant running twelve hours a day. On a 24-hour basis, with the introduction of some additional economies, this grade of alcohol could be produced at a cost between 0.070 0.075 peso (0.035 and 0.0375 dollar) per liter. These figures include the overhead expense of the distillery and nipa groves, that is, the cost of administration.

Although at the present time 98.8 per cent of the total quantity of alcohol produced in the Islands is consumed in the various beverages,⁹ it is evident that we have in the nipa palm a promising source of industrial alcohol. Certain species of palms thus assume a commercial importance in the Philippines which they do not attain in any other country.

The nipa palm also gives great promise of being a commercial possibility as a source of refined sugar (sucrose). In another part of the paper I shall introduce data which will serve to demonstrate this conclusion.

Many references to the occurrence of sugar in palm saps are to be found in the literature, for the natives of some tropical countries have, from time immemorial, made crude sugar from this source.

E. O. von Lippmann¹⁰ states that the saps of many species of palms, for example, *Arenga saccharifera*, *Phoenix silvestris*, *Caryota urens*, *Borassus flabelliformis* (*B. flabellifer*), *Cocos nucifera* contain from 3 to 5 per cent sucrose.

M. Berthelot¹¹ identified the sugar from the Java palm *Saguerus rumphii* (*Arenga saccharifera* Labill.) as sucrose.

⁸ In the Philippines, it is probable that alcohol can be produced from cassava at a lower figure than this.

⁹ The figures for the fiscal year 1909 are: Total production, 9,532,537 proof liters; consumed as beverages, 9,423,870 proof liters; withdrawn for export, 81,995 proof liters; and used for industrial purposes, 26,672 proof liters; and for the fiscal year 1910, 10,584,124, 10,392,422, 8,020, and 183,682 proof liters, respectively.

¹⁰ Die Chemie der Zuckerarten, Braunschweig (1895), 590.

¹¹ Ann. d. chem. et d. phys. (3) (1859), 55, 286.

Analyses of sugar from the date palm (W. Wallace) and East Indian palms (?) (Winger and Harland) are reported in Allen's Commercial Organic Analysis.¹²

P. Horsin-Deon¹³ gives the analysis of sugar from Calcutta palms.

H. C. Prinsen Geerligs¹⁴ states:

"Sugar is found in a great many plants, dissolved in the sap. Although it may be considered as one of the most universal constituents of plants, only a few of them contain it in such a degree and so sparingly mixed with other bodies as to allow of its profitable extraction. Such are: the sugar cane, the beetroot, the sorghum, the coco, date, palmyra and nipah palms, and the maple tree; then bees extract it from the flowers of many plants, but in this case it is soon converted into invert sugar."

Beverages manufactured from palm saps have been of economic importance to the people from the earliest history of the Philippine Islands.

The first record of the manufacture of palm wine by the natives of these Islands is made by Antonio Pigafetta,¹⁵ the historian of Magalhães' expedition around the world. Throughout his account, Pigafetta writes that the natives of the various islands where they touched, made and consumed large quantities of palm wine. On March 16, 1521, the vessels bearing the first Europeans to sight the Philippines, arrived at the Island of Samar and two days later the natives presented among other things, a jar of palm wine which they termed *uraco*. Pigafetta writes as follows concerning this beverage:

"They get wine [from the coconut palm] in the following manner. They bore a hole into the heart of the said palm at the top called palmito [*i. e.*, stalk], from which distils a liquor which resembles white must. That liquor is sweet but somewhat tart, and [is gathered] in canes [of bamboo] as thick as the leg and thicker. They fasten the bamboo to the tree at evening for the morning, and in the morning for the evening."

Regarding his experiences while dining with the king of Mindanao he states:¹⁶

"Until the supper was brought in, the king with two of his chiefs and two of his beautiful women drank the contents of a large jar of palm wine without eating anything."

Maximilianus Transylvanus,¹⁷ who was also with the expedition, writes, in a letter to the Cardinal of Salzburg, that while at the Island of Cebu, the natives brought the admiral and some of the officers into the chief's cabin, and set before them what food they had.

"The bread was made of sago, which is obtained from the trunk of a tree not much unlike the palm. * * * their drink was a liquor which flows from the branches of palm-trees when cut * * *"

In 1565, the trade between Governor Legaspi's men and the natives became very brisk and the records state:¹⁸

"Among other things the natives traded 'a great quantity of palm wine, to

¹² Phila. (1890), 1, 301.

¹³ Bull. Soc. Chim., (1879), nouvelle série, 32, 125.

¹⁴ Cane Sugar and its Manufacture. Manchester (1909), 3.

¹⁵ Blair and Robertson. The Philippine Islands (1906), 33, 105.

¹⁶ Ibid. 203.

¹⁷ Ibid. 1, 323.

¹⁸ Ibid. 2, 137.

which the Spaniards gave themselves with good appetite, saying they did not miss the wine of Castilla * * *."

Mercado¹⁹ in his work written between 1665 and 1698 mentions that in the Philippines, a *tuba* is obtained from the coconut palm which is medicinal and good for refreshing the liver; from *caryota*, a sweet *tuba* which on fermentation is intoxicating; from *buri*, a *tuba* from which the natives make vinegar and by boiling when fresh, a sugar which they call *pacascas*; and in Pampanga Province a wine from the *nipa*.

At the present time several different species of palms are employed for the production of sap from which fermented and distilled beverages are manufactured. The fresh or fermented saps the natives designate by the name *tuba*. The fermented saps by distillation yield the alcoholic drink locally known as *bino*, *vino* the Spanish word for wine, or *alak*, the Tagalog word usually applied to a distilled beverage corresponding to *arak* or *arrack* of other Malaysian dialects. In many localities, the unfermented palm-saps are used as a source of sugar. This sugar is made by evaporating the palm-juice by boiling in open pans or kettles in much the same manner as maple sugar is prepared from the sap of the maple tree in the United States.

The three species of palms which are now most extensively utilized for the sap are the *nipa* (*Nipa fruticans* Wurmbr.), which grows gregariously and in great abundance throughout the Islands about the mouths of estuaries of tidal rivers; the coconut (*Cocos nucifera* Linn.), extensively cultivated throughout the Archipelago; and the *buri* (*Corypha elata* Roxb.) found throughout the Islands at low and medium altitudes, wild and uncultivated, and also planted.

In India, Australia, Malaya, and other places, various other species of palms yield saps in abundance, which are utilized for making *toddy* and *arrak*, corresponding respectively to our *tuba* and *bino*. Among the palms thus utilized may be mentioned: *Arenga saccharifera* Labill., the sugar palm; *Borassus flabellifer* Linn., the Palmyra palm; *Caryota urens* Linn., fish-tail palm; *Phoenix dactylifera* Linn., the date palm; and *Phoenix sylvestris* Roxb., the wild date palm.

Some of these species extend to the Philippines. *Arenga saccharifera* Labill. is locally known as *caong* and sometimes *cabo negro*.²⁰ The genus *Caryota* is represented by several species locally termed *pugahan*, closely allied to *C. urens* Linn., while the sago palm (*Metroxylon rumphii* Mart.) is abundant in parts of Mindanao and in some other islands. As sap-producing palms, these are at present of but little commercial importance in the Islands.

On the other hand the *nipa* and the *buri*, the former extensively utilized in the Philippines as a source of alcohol and alcoholic beverages,

¹⁹ Libro de Medicinas de esta Tierra, Manila (1880), 1, 50.

²⁰ Refers more particularly to the fiber obtained from this palm.

and the latter to some degree, do not appear to be used for this purpose in India, although both occur there.

The analyses of the saps of the Philippine palms show a variation in different individuals, of the same species due to local conditions, and also in the sap of the same palm at different periods of the sap flow. Nevertheless, there is a remarkable uniformity in the composition of the saps of the different species; in general, those of the best quality were found to be practically of the same composition, about as follows:

Density $\frac{15^{\circ}}{15^{\circ}}$	1.0700
Solids	17.5 per cent.
Acidity	Trace.
Ash	0.46
Sucrose	16.5
Reducing sugars	Trace.
Nitrogenous compounds and undetermined	0.54

Samples of about this character have been obtained from the nipa, coconut, buri, and arenga palms.

The saps as they exude from the trees are practically neutral and contain no sugar other than sucrose. The processes of inversion of the sucrose and fermentation commence almost immediately.

Considerable difficulty was experienced in preserving the samples for any length of time before analysis. The preservatives tried were mercuric chloride, formaldehyde, chloroform, toluene, alcohol, lime, and sterilization by heat. The last is undesirable, since, in the cases investigated, it produces changes in the sap. The nitrogenous bodies break down forming basic nitrogen compounds which make the juice strongly alkaline. Mercuric chloride is also undesirable for the reason that it forms a heavy precipitate with the nitrogenous compounds and does not inhibit all other changes in the sap. Lime or calcium hydroxide is only useful when the sap is utilized for the production of sugar. Alcohol is very useful, the only change produced in the exuded sap being the precipitation of nitrogenous matter as flocculent white substances which settle, leaving a clear, supernatant liquid. For analytical purposes the alcohol does not interfere, since the original composition of the sap can be calculated. Toluene, formaldehyde, and chloroform, when put into the bottles and the sap allowed to drop from the tree into the preservative, give satisfactory results, provided the bottles are completely filled and then tightly stoppered. When access of air is possible, the inversion of the sucrose is not stopped by the preservative. The inversion is too rapid to be due to the acids formed, and results from an invertase which forms from a zymogen. These and a number of other subjects are discussed under their proper headings in the following pages.

The uses to which the palm trees and their products are put by people of all grades of civilization are almost innumerable. It is difficult to overestimate their value to the native population and to tropical agriculturists. They furnish food, shelter, clothing, timber, fuel, building materials, sticks, fencing, fiber, paper, starch, sugar, oil, wax, wine,

tannin, dyeing materials, resin, and a host of minor products. The coconut palm in all probability, lends itself to a greater variety of uses than any other. The buri palm is employed to a very great extent in the Philippines in the production of many useful native products and in this respect it shares honors with the coconut, although it is not of great commercial importance at the present time. In some tropical and semi-tropical countries outside this Archipelago other palms are put to varied uses by the natives.

In certain arid regions, the date palm reaches supreme importance. Many parts of Arabia and the Sahara would not be habitable without it.

Swingle²¹ states as follows regarding this palm:

"Not only does it yield a delicious fruit of great food value, but it also furnishes in many regions the only timber suitable for use in the construction of houses and for making a thousand and one necessary objects. * * * For centuries, the transportation of dates has been the chief motive for the formation of the great caravan routes which run in every direction through the deserts in Africa and Arabia."

It is extremely probable that the first *palm wine*, a product of the fermentation of the exuded sap, was made from the date palm which has been grown along the Euphrates and Tigris rivers for over 4,000 years. Small quantities of an alcoholic beverage are still made from this source.²² The only analysis of this wine which I have been able to find in the literature was made by Balland²³ and is as follows:

Analysis of a sample of palm wine from Lagouat, Arabia, made from the sap of 40-year-old date palms.

Water	83.80
Alcohol (equivalent to fermentable sugars 9.20 grams)	4.38
Carbon dioxide	0.22
Malic acid	0.54
Glycerol	1.64
Mannitol	5.60
Reducing sugars	0.20
Gum	3.30
Ash	0.32
	<hr/> 100.00

An "acid-sweet sap" is obtained for the manufacture of alcoholic beverages from other species of palms, unknown in the Philippines.

Martelli²⁴ states that the saps of the African palms, *becrari*, *bajudi*, and *tabuni*, ferment rapidly, producing *lakmi*, *lakby*, *legbby* or palm wine. *Legbby*, from

²¹ *Yearbook U. S. Dept. Agric.* (1900), 452; and *Bull. U. S. Bur. Plant Ind.*, (1904), No. 53, 13.

²² Kearney and Means. *Bull. U. S. Bur. Plant Ind.* (1905), No. 80, 70. "Trees of inferior value are made to yield 'lagmi,' or palm wine, a sweet juice which is obtained in abundance by cutting the bud at the summit of the stem."

²³ *Compt. rend. Acad. Sci.* (1879), 98, 262.

²⁴ *Ztschr. f. Untersuch. d. Nahrungs- u. Genussmittels* (1910), 3, 200.

the *becrari* palm, contains acetic and malic acids, and the analysis shows the following constituents:

Acids as acetic	0.446
Reducing sugars	3.299
Nonreducing sugars	3.313
Protein	0.015
Ash	0.353
The ash contains	
Potash (K_2O)	63.675
Soda (Na_2O)	6.77
Lime (CaO)	5.10
Magnesia (MgO)	3.21
Sulphuric anhydride (SO_3)	6.086
Phosphoric anhydride (P_2O_5)	8.15
Silica (SiO_2)	5.93
Iron and undetermined	1.09

Leghby, from tabuni palms, has the following composition.

Acidity as acetic	0.413
Reducing sugars	3.167
Nonreducing sugars	1.596
Ash	0.392
The ash.	
Phosphoric anhydride	7.726
Sulphuric anhydride	4.157

NOTE.—My grateful acknowledgements are due to the Bureau of Internal Revenue and its agents in the various provinces which I visited, for assistance and many valuable data; to Mr. Hugo Miller of the industrial division of the Bureau of Education, for the distribution maps, the charts of the uses of the various palms, and for other valuable assistance; to Dr. E. B. Copeland, Dean of the College of Agriculture of the University of the Philippines, for reading part of the manuscript and for many valuable suggestions; and to the managers of several Philippine distilleries, principally Ayala and Company and Ynchausti and Company, for many kindnesses during my numerous visits. The botanical identifications and descriptions were made by Mr. E. D. Merrill of the Bureau of Science.

THE NIPA PALM.

Nipa fruticans Wurm.

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DESCRIPTION.

The nipa is an erect, stemless palm, the leaves and inflorescences arising from a branched rootstock, the leaves pinnate, 3 to 10 meters long. Inflorescence from near the base of the leaves, erect, brown, 1 to 1.5 or 2 meters high, bearing numerous sheathing spathes and both male and female flowers, the former lateral, catkin-like, the latter terminal in a globose head. Fruit nodding, globose, as large as a man's head or often considerably larger, consisting of many abovoid, 6-angled, 1-celled, 1-seeded carpels, the free parts pyramidal, the pericarp fibrous, the seed large, white, hard.

HABITAT AND DISTRIBUTION.

This palm grows only along the mouths of tidal rivers in low, wet lands subject to overflows of brackish water as the tides rise each day, and it will not thrive in localities where either fresh or sea water alone is available.

Nipa swamps of considerable size and importance occur in a number of provinces in the Philippines.

Map No. 1 shows the distribution in the Islands.

This map is compiled from information obtained by the industrial division of the Bureau of Education through the industrial schedules sent out in the year 1910 to each town in the Philippines, and as a consequence there is information on file as to whether much, little, or no nipa swamp is located in the vicinity of each town. Where doubt existed as to the correctness of the information an attempt was made to check it by correspondence with division superintendents, and in several instances maps of provinces showing the nipa areas have been submitted. Rated in the order of their size, irrespective of their present commercial importance, the most extensive areas are situated as follows:

Portions of the Provinces of Pampanga and Bulacan bordering on Manila Bay,



Philippine Islands Base Map 1905.

MAP NO. 1.

Mercator projection 5000000 in lat. 13°N

Island of Luzon. Province of Capiz, Island of Panay. The valley of the Cagayan River, Island of Luzon. The valleys of the Catubig and the Gandara Rivers in the Island of Samar. The Province of Pangasinan, Island of Luzon. Surigao, Island of Mindanao. The Province of Tayabas, Island of Luzon.

The other nipa areas of the Philippines do not compare in size with those listed above. Doctor Foxworthy, of the Bureau of Science, informs me that there are nipa areas in Borneo greater than any which exist in the Philippines.

Swamp lands, subject to daily overflow by the tides, to the uninitiated would appear to be of no value, but it will be shown later to how great an extent the nipa palm, growing in great abundance in these localities, gives a profitable crop when properly exploited.

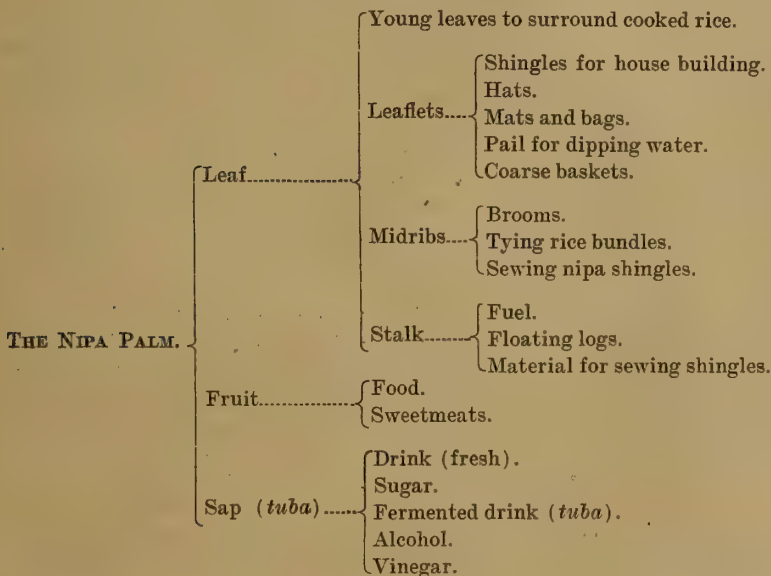
USES.

The various parts of the nipa palm lend themselves to a variety of uses in the Islands, some of which are only of great value to the natives; for example, the employment of the leaves for house thatch and shingles.

The production of alcohol from the sap is an industry which to-day is of great commercial importance and in the future promises marked advancement and profits to invested capital. So far as I have been able to find, the production of alcohol on a commercial scale from this source is unique to the Philippines, and even here it is developed only to a very small fraction of its possibilities.

The various uses to which the palm is put are as follows:

The uses of the nipa palm.



The scope of this investigation has been confined to the sap production, its commercial status and possibilities.

THE NIPA DISTRICT WHICH BORDERS ON MANILA BAY.

This district ranks first in area and commercial importance. Its development is largely due to its proximity to Manila, which is the main market for the alcohol, and to the fact that labor questions in this locality cause less trouble to the owners and distillers than in other provinces of the Islands. Since the conditions which have been developed in this district are characteristic of what can be done in many other places, and also, since the major portion of the investigation was carried on in it, this nipa swamp is more fully described.

An ideal habitat for this plant is found in a very extensive plain scarcely above sea level on the north side of Manila Bay. The three rivers, the Vetis, the Grande de Pampanga, and the Chico, on reaching this plain divide and subdivide into many channels and waterways, which, as they approach the bay, repeat the process and form innumerable islands, large and small, upon which the nipa palm thrives. The land is gradually encroaching upon the water area, because of the silt deposited by the rivers. The nipa is quick to take advantage of any foothold it may obtain, and while it may not occupy the outposts of vegetation it assists in holding the deposited soil, and hastens the encroachment upon the sea, at the same time extending its own area for growth.

This nipa area lies in the Provinces of Bulacan and Pampanga, on the Island of Luzon, and extends along Manila Bay for 32 kilometers. The average width is about 5 kilometers, but in some places the growth of plants extends up the rivers for a distance of about 16 kilometers from the bay. The area is conservatively estimated at 18,000 hectares. A considerable portion of these swamp lands is owned or controlled by various large distilleries, the headquarters of which are in Manila. The largest holdings are: Ayala and Company, in Pampanga, 3,800 hectares; Paulino Estrella, Hagonoy, Bulacan, 800 hectares; the municipality of Hagonoy, 437 hectares; and Benito Mojica, Pampanga, 400 hectares. Only about 30 per cent of the total area of this district is at present being utilized, namely, that part which lies along the edges of the waterways and is easy of access and within short walking distances of the distilleries. It is estimated by Mr. Augusto Yrastorza²⁸ that 6,450 hectares are at present being worked for the sap.

On some of the nipa estates, artificial canals have been dredged to extend the areas fitted for the growth of the plant and to make all parts of the estate accessible in small boats. In many places as new canals have been completed the plants have been greatly increased in numbers by cultivation, transplanting, and the distribution of seeds. In others the nipa area is being reduced by the turning over of the land to the construction of fish ponds, which appear for the moment to be productive of a greater income from the investment.

²⁸ Mr. Yrastorza is manager of the distillery of Ynchausti and Company at Hagonoy, Barrio Santo Rosario, Bulacan. I am greatly indebted to him for much information and kindness shown me while visiting the plant.

THE WORK IN THE NIPA SWAMPS.

The best managed *nipales*, or nipa groves, are divided into sections of about 1 hectare, containing from 700 to 800 producing plants in every hectare,²⁶ each of which is assigned to the care of one or more men. Usually two men are required to handle 1 hectare and the work of cutting the plants, gathering and transporting the *tuba* to the distillery and the general care of the grove is divided between them. Since the sap not only has a recognized commercial value at the distillery, but is also greatly prized by the natives as a beverage, a close watch by the guards is necessary.

The sap, as it drops from the flower stalks, is collected in hollow joints of bamboo. Each plant is visited daily and the sap brought to the distillery in *bancas*²⁷ of light draught which the natives paddle in and out of the waterways. Sometimes the *tuba* is emptied into large earthenware jars and these are transported to the distillery, and, again, it is emptied directly into the boat. A nipa leaf is cut and placed in the banca over the *tuba* to prevent undue slopping, and thus, more or less immersed in the partially fermented *tuba*, the boatmen make the trip. The time for gathering the sap is in some measure dependent upon the tides, for many of the small waterways are navigable only with difficulty or else are impassable at low tide, even for such a light draught vessel as the native canoe. The collection in some localities begins at 1 o'clock in the morning and is completed within 6 hours.

The laborer in the nipa groves builds himself a house of nipa leaf thatch with bamboo framework, on the bank of a stream on the nipa estate. Fish, the principal article of food, are easily caught in these places. Here, usually with a large family, he lives in peace and contentment.

THE SAP.

Historical.—It is probable that the natives of this Archipelago fermented beverages from the nipa sap before the arrival of Europeans in 1521.

The historians of Magalhães's expedition continually mention the use of palm wine without specifically referring to the nipa, although the coconut palm is mentioned. Oliver van Noordt²⁸ reported (1598 to 1601), "All these islands * * * produce abundance of rice and wine made from nypa." Mercado,²⁹ prior to 1698, writes that the natives of Pampanga Province made an intoxicating beverage from the nipa sap.

²⁶ The total number of plants in this area is more than double this number. This is explained later under the heading "Yield of sap."

²⁷ A Philippine canoe, hewn out of a single log.

²⁸ Blair & Robertson. *Loc. cit.* 11, 302.

²⁹ *Loc. cit.*

Watt³⁰ states that Luischaten, nearly 300 years ago, in his Account of a Voyage to the East Indies, mentioned that the *toddy* obtained from the spathe of the nipa palm yielded an excellent wine.

About seventy years ago, according to native story in Bulacan, it was observed that rats (some people say deer) seemed to be very fond of eating the broken or crushed fruit stalks of the nipa palm injured by roaming carabaos. It was found on investigation that the bruised places exuded a sweet juice which could be made to flow more plentifully by cutting the stalks, and which was found to be a pleasant beverage. It fermented very rapidly and was drunk by the natives both in the fresh, sweet state and after fermenting.

Another story which is told among the natives, is that the discovery of the properties of the nipa palm is due to an accidental severing of the peduncle while an old man was cutting wood for kindling. He noticed the clear liquid which exuded and as he was thirsty at the moment he applied his lips to the cut and found that the sap was very sweet and fresh. A very long time after, the distillation of the sap was practiced.

The first firm to take advantage of these discoveries on a commercial basis was that of Ayala and Company. In 1834 they built distilleries in San Esteban, Pampanga, and in Manila, and equipped them with apparatus of French manufacture. Prior to that time the ancient *caua*, a crude distilling apparatus manufactured from a hollow log and bamboo tubing, was employed. The apparatus and buildings are still in use and it is possible that some of the first plants tapped by Ayala and Company are still producing tuba.

Tapping the palm.—Since the nipa sends its inflorescence up from the base and hence is near the ground, the flower stalk is conveniently situated for the gathering of the sap. Four years after planting the seed, the nipa bears small fruits, but it is not tapped for its tuba until the fifth year. Some time after the fruit has formed, the stalk is cut across near its top, usually just below the fruit, and each day a thin slice is removed to keep the wound fresh and to facilitate exudation.³¹ When a plant bears two flower stalks the usual practice is to draw sap from only one, the other being removed and the stem allowed to dry up.

The sap is collected in bamboo joints, called *tuquils* (Pampangan) or *bombones* (Spanish), which are hung upon the stem. The receptacles are about 45 centimeters high and 8 centimeters in diameter and have a capacity of about 2 liters.

One stalk normally flows for about three months, but it is not uncommon for it to be entirely cut away, at least so close to the ground that it can no longer be utilized by the daily paring of small slices to keep the wound fresh, long before the flow has ceased. In some districts the

³⁰ Dictionary of Economic Products of India, London and Calcutta (1891), 5, 430.

³¹ According to native superstition the stalk must be kicked, in passing, once a week for five weeks, before it is cut or the sap will not flow freely. In some localities this practice is performed three times a week for five weeks. In reality this is a process of bending down the flower stalk so that the tuba issuing from it can more easily be collected in the bamboo receptacles. The yield is supposed to be increased on shaking and bruising the stalk.

flower is cut before the fruit is formed and under such circumstances the daily yield of sap is said to be increased, but the period of flow reduced from three to one and one-half months, the total yield being practically the same in both cases. The plant seemingly is not affected by this treatment. The tuba season is usually of six months' duration. As a rule it commences in Luzon in August, sometimes as early as July, but it is subject to varying climatic conditions. In some areas only a portion of the palms are cut at the beginning of the season in order to supply the distilleries with tuba throughout the year and thus avoid shutting down the plant. As these palms are exhausted, the others are brought into production by cutting, and thus the season becomes continuous. No accurate estimates of the length of the time during which the nipa palm will continue to fructify and give tuba are available, but all observers unite in saying that this process will continue for many years, perhaps for fifty or more.

Yield of sap.—The estimates of the yield of sap vary within very wide limits. A distiller who has had much experience in the *nipales* believes that each producing plant will average 1.25 liters daily, and a chemist at one time employed by one of the distillers has stated that an average plant will flow 50 liters during the season.

The yield per hectare has been estimated by many different writers and distillers and it is evident from a perusal of the figures that many are mere guesses. The number of plants per hectare is estimated by a chemist in the employ of one of the distillers to be 2,500. Internal Revenue Agent G. A. Ruge believes the municipalities of Abulug and Pamplona in the Province of Cagayan to have *nipales* containing 4,600 plants per hectare.³² A distiller of wide experience told me that the number is 700. If this latter figure is taken to be 700 plants producing at the same time I have no doubt that it is fairly accurate for the areas controlled by his company. He also stated that they obtained in actual practice 438 liters per hectare daily during the season. This is equivalent to 78,480 liters yearly per hectare,³³ a figure quite close to my estimates. Other figures, not so reliable, go as high as 225,000 liters per hectare.

It is to be remembered that while wild nipa swamps may contain 4,000 plants per hectare, the percentage of producing plants and the amount of sap which each plant yields will be less than in the cultivated districts. In the uncultivated areas a small proportion of the trees is accessible; in the cultivated, the plants are thinned, and there are more waterways, and yet the yield of sap per hectare is greatly increased. A yield of 75,000 liters of tuba per hectare per year would be extremely satisfactory to the distillers, and I believe this amount is seldom

³² Unpublished report to the Collector of Internal Revenue. "In obtaining the data as to the number of plants per hectare, I measured off 10 meters square in various localities in each of the districts of Abulug and Pamplona. An effort was made to secure the average amount of tuba each plant produced, which effort, however, proved a failure because the tuba was continually stolen. I have every reason to believe that the average amount of tuba per plant will not fall below 1,000 g." (per day).

³³ Allowing 180 days for the collection of sap.

reached in the best managed *nipales*. It should, however, be exceeded. Some operators obtain only 4,000 liters per hectare during a full season.

In the year 1909 one of the largest producers obtained 8,700,000 liters of tuba from an estimated area of 1,000 hectares which is at the rate of 8,700 liters per hectare. Less than one-third of this area was producing, partly from lack of labor and partly because the greater portion of the estate had not been made accessible to the distillery. The alcohol production from this yield was about 5 per cent.

The atmospheric and climatic conditions affect the flow of sap. The natives working among the plants are positive that they can predict the approach of a storm by a sudden checking, in some cases amounting to almost a stoppage, in the flow, occurring about three days before the arrival of the typhoon. It is stated that after a temporary stoppage has been produced by meteorologic conditions an increased flow will start which will balance the period of inactivity.

The seasonal variation in the composition of the fresh tuba must be slight, although when received at the distilleries the differences, both in quality and quantity, are very great. This is undoubtedly due to the fact that rains dilute the juice after it has flowed from the flower or fruit stalk. The gain in volume is balanced by the loss in sugar and alcoholic content.

As a result of the experimental work performed by myself and others associated with me in this work, I believe that the average conditions in a *nipale* cared for according to present methods will result in a yield of 43 liters for each plant during the season, an average daily yield during the period of production of 0.58 liter and a total yield of 87,000 liters per hectare per year.

The number of plants per hectare.—Mr. R. R. Williams, of the division of organic chemistry of the Bureau of Science, at my request made a careful estimate of the number of plants per hectare and he writes as follows concerning his investigations:

The swamps of Bulacan and Pampanga average about 2,000 to 2,250 nipa plants per hectare, including both water and land surface. This estimate is based on actual counts on measured areas, after having explored a hundred kilometers or more of the channels and traversing afoot the interior portions of the swamps in numerous places.

A strip 1 kilometer long and 10 meters wide through the unworked swamps of Ayala and Company near Consuelo showed 2,170 plants per hectare. The first 500 meters of this strip gave an average of 2,600 plants, while the second tallied only 1,750 per hectare. This difference is due to many low spots and ponds covered or surrounded by growth other than nipa. The entire swamp is foul and not cared for. A similar strip through the Buencamino swamps near the *barrio* of Song Fo, aggregating an area of over 7,000 square meters, averaged 2,410 plants per hectare. This strip also traversed small areas where nipa was largely replaced by mangrove or grasses. A rectangular area of 3,200 meters in the immediate vicinity tallied 2,600 trees per hectare. This plot embraced only clean, well kept swamp, unbroken by water courses. A similar strip 500 meters in length through swamps exploited by Ynchausti and Company south of

Hagonoy contained 2,700 trees per hectare, while a clean unbroken rectangular area of 2,000 square meters showed a little over 2,800 plants per hectare. Rough counts in various places on small plots confirmed the estimate for clean land areas of about 2,500 to 2,700 plants per hectare. Water courses, ponds, and foul patches will reduce the average for the whole region to about 2,250 or possibly 2,000.

The yield of sap from each plant.—Four plants originally investigated in the early stages of this work, yielded during a 17.5 hours' flow a highest number of 890 cubic centimeters and a lowest of 240 cubic centimeters, the average for the four plants was 606 cubic centimeters. This observation, in view of later data, seems to be too high.

Six average plants on the San Esteban estate were tapped by skilled natives at 6 o'clock in the morning of November 21, 1910, and the sap flow measured each twenty-four hours during the entire sap flow. The duration of the shortest flow was fifty-three days, while that of the longest was seventy-five days.

The data are recorded in Table V.

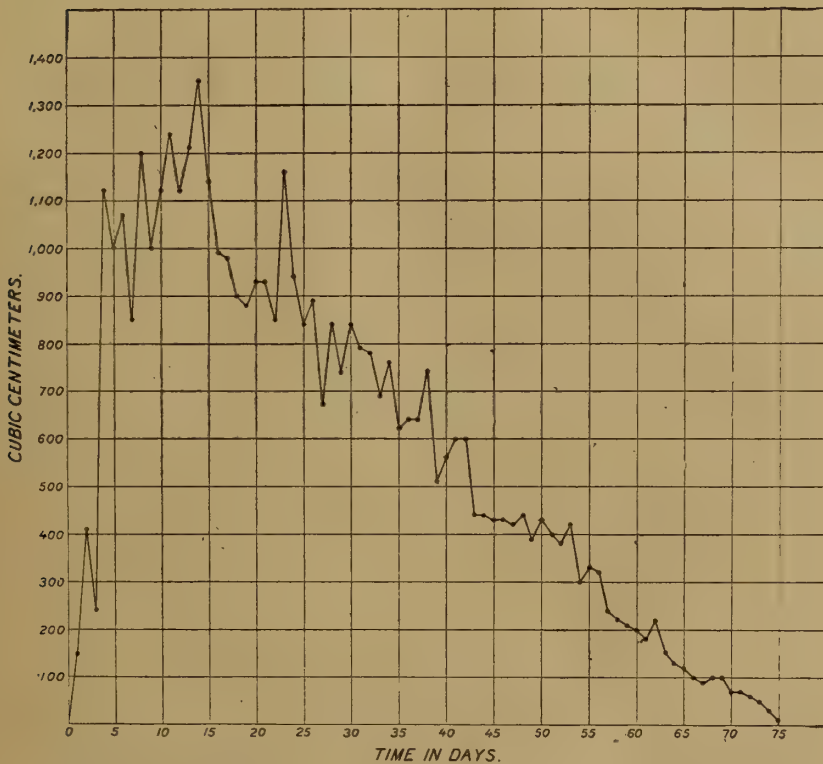
TABLE V.—*The sap flow, in cubic centimeters, from six nipa palms during the entire period of one season's production.*

Days.	Date.	Number of palm.						Average.
		1	2	3	4	5	6	
	1910.							
1-----	Nov. 22	180	230	245	60	45	180	149
2-----	Nov. 23	275	375	430	310	910	145	408
3-----	Nov. 24	175	310	260	280	45	345	236
4-----	Nov. 25	620	1,240	1,400	1,300	566	1,600	1,121
5-----	Nov. 26	965	1,200	1,420	465	760	1,205	1,003
6-----	Nov. 27	1,000	1,150	275	1,275	1,770	980	1,075
7-----	Nov. 28	1,170	1,010	130	885	780	1,105	847
8-----	Nov. 29	1,100	1,200	1,550	1,300	750	1,275	1,196
9-----	Nov. 30	1,155	1,055	305	1,300	1,035	1,150	1,000
10-----	Dec. 1	1,050	720	1,500	1,250	900	1,300	1,120
11-----	Dec. 2	1,125	1,215	1,760	1,200	1,000	1,200	1,240
12-----	Dec. 3	1,150	1,180	1,350	1,080	700	1,270	1,122
13-----	Dec. 4	1,125	1,310	1,500	1,110	955	1,250	1,209
14-----	Dec. 5	1,680	1,250	1,620	1,305	600	1,625	1,347
15-----	Dec. 6	1,000	1,250	1,500	1,020	755	1,300	1,138
16-----	Dec. 7	925	1,250	1,350	1,000	565	870	993
17-----	Dec. 8	1,000	1,100	1,300	850	350	850	908
18-----	Dec. 9	1,000	1,225	1,500	600	350	725	900
19-----	Dec. 10	820	1,175	1,115	1,000	350	800	877
20-----	Dec. 11	850	1,065	1,100	825	650	1,000	915
21-----	Dec. 12	850	1,065	1,100	825	650	1,000	915
22-----	Dec. 13	550	750	1,000	1,150	600	1,060	852
23-----	Dec. 14	1,000	1,000	1,500	1,220	1,000	1,250	1,162
24-----	Dec. 15	1,000	810	1,300	1,000	750	800	943
25-----	Dec. 16	780	510	1,220	730	920	850	835
26-----	Dec. 17	820	650	1,120	960	1,000	760	885
27-----	Dec. 18	510	520	1,180	550	550	720	671
28-----	Dec. 19	850	640	1,000	710	840	1000	840
29-----	Dec. 20	750	480	900	710	800	810	741

TABLE V.—*The sap flow, in cubic centimeters, etc.—Continued.*

Days.	Date.	Number of palm.						Average.
		1	2	3	4	5	6	
	1910							
30	Dec. 21	700	710	800	950	860	1,010	838
31	Dec. 22	810	450	810	770	850	960	775
32	Dec. 23	780	600	460	950	850	940	763
33	Dec. 24	770	450	480	650	820	960	688
34	Dec. 25	730	500	850	680	840	940	757
35	Dec. 26	580	480	560	750	600	750	620
36	Dec. 27	740	230	410	800	760	900	640
37	Dec. 28	750	260	450	800	810	760	638
38	Dec. 29	650	550	600	800	950	920	745
39	Dec. 30	610	300	450	580	630	500	512
40	Dec. 31	580	450	500	600	720	600	575
	1911.							
41	Jan. 1	500	450	600	810	530	710	600
42	Jan. 2	540	300	620	800	640	720	603
43	Jan. 3	510	280	420	510	260	660	440
44	Jan. 4	500	250	450	620	250	620	448
45	Jan. 5	530	250	460	660	150	560	435
46	Jan. 6	540	240	450	550	250	610	440
47	Jan. 7	400	280	390	400	460	600	421
48	Jan. 8	500	140	410	610	490	500	442
49	Jan. 9	540	260	150	600	450	360	393
50	Jan. 10	520	360	350	680	500	150	427
51	Jan. 11	500	350	400	510	500	150	402
52	Jan. 12	300	290	450	500	610	100	375
53	Jan. 13	550	310	450	520	620	60	417
54	Jan. 14	460	200	360	350	440	0	302
55	Jan. 15	430	190	420	460	480		330
56	Jan. 16	400	250	410	360	500		320
57	Jan. 17	400	20	360	290	380		242
58	Jan. 18	370	0	340	300	410		237
59	Jan. 19	400		370	250	260		213
60	Jan. 20	350		260	250	350		202
61	Jan. 21	300		320	260	200		180
62	Jan. 22	390		310	290	340		222
63	Jan. 23	140		260	200	300		150
64	Jan. 24	40		300	190	250		130
65	Jan. 25	0		260	190	270		120
66	Jan. 26			250	150	200		100
67	Jan. 27			230	140	210		97
68	Jan. 28			210	190	210		102
69	Jan. 29			250	180	160		98
70	Jan. 30			160	110	140		68
71	Jan. 31			150	130	140		70
72	Feb. 1			120	100	160		63
73	Feb. 2			140	0	150		48
74	Feb. 3			90		110		33
75	Feb. 4			0		80		13
76	Feb. 5					0		0
Total		43, 235	36, 335	49, 410	46, 760	41, 086	43, 460	43, 381

The daily yield is shown in the following diagram:



TEXT FIG. NO. 1.—Sap flow of nipa palm. Average of six trees during one season.

The following data are obtained from the above table:

	Liters.
Total flow from six trees	260.286
Greatest total flow from a single tree	49.410
Lowest total flow from a single tree	36.335
Average seasonal flow per tree	43.381
Average daily flow from six trees	3.470
Greatest daily flow from one tree	1.770
Average daily flow per tree	0.579

Although I have much confidence in Mr. William's count of 2,250 producing trees per hectare, I believe it safer to base estimates of areal production upon 2,000 trees per hectare. On this basis the yield per hectare per year is 86,862 liters.

I believe that both the yield and quality of sap can be improved by the planting of selected seed and by improved methods of caring for the *nipales*.

COMPOSITION OF THE SAP.

(In coöperation with F. AGCAOILI.)

The sap as it flows from the stalk is clear and transparent, almost colorless, and very sweet to the taste. Samples from six different palms in the Provinces of Bulacan and Pampanga were studied to determine the composition.

The native tuba gatherers stated that the first four palms had fruited in August, but that the flower stalks had been cut for only one month and had been running sap ever since. They believed that the flow would continue for more than another month, but that the flower stalks would be cut away entirely before the flow ceased. The palms were more than thirty years old. The estimated daily flow may not be quite correct for the reason that it is based upon the amount collected during the night following the fresh slicing of the stem, when the sap flow is somewhat greater than during the day, when the cut surface is not fresh. Samples numbered 5 and 6 were, from all the information which could be gathered, from trees of about the same age and, to all intents and purposes, in the same condition as the first four. All of the trees were average specimens representative of the whole district, which contains millions of palms.

The analytical data are tabulated as follows:

TABLE VI.—*Analyses of the sap of the nipa palm.*

Sample number.	Flow from one flower stalk during 17½ hours, 4:30 p. m., 10 a. m., February 16 and 17, 1910.	Rate per day in liters	Density 15°.	Total solids in 100 grams.	Acidity as acetic in 100 cc.	Ash.	Polarization at 30° 26.048 g.	Invert reading at 30°.	Sucrose by Clerget's formula in 100 grams.	Sucrose in 100 cc.	Invert sugar in 100 cc.	Purity.
	cc.						+	—				
a ¹	695	0.953	1.0633	15.40	0.43	0.39	5.0	2.20	5.50	5.85	7.31	-----
a ²	240	0.324	1.0654	15.39	0.27	0.65	12.4	2.86	11.83	12.60	0.74	-----
b ³	890	1.221	1.0679	17.03	0.10	0.47	14.0	2.42	12.73	13.60	0.89	-----
b ⁴	600	0.823	1.0714	18.36	0.03	0.48	15.6	4.42	15.42	16.58	0.80	-----
5	Dec. 14	-----	1.0644	c 15.7	-----	-----	14.1	-----	-----	14.95	-----	89.8
6	Dec. 14	-----	1.0730	c 17.7	-----	-----	16.2	-----	-----	17.32	-----	91.5

^a Preserved with 1 g. mercuric chloride.

^b Preserved with 1 cc. formalin.

^c Calculated from the density. *Bull. U. S. Dept. Agric. Bur. Chem.* (1908), No. 107, 221.

The first four samples were collected at Hagonoy, in glass bottles containing the preservatives and analyzed in the laboratory in Manila two days later. Samples numbered 5 and 6 were taken from two trees at San Esteban and polarized immediately. To avoid all external

influences the polarization tubes were hung on the flower-stems at the point where the sap dropped.

The tubes were partially filled with toluene which was displaced as the sap dropped into the tube. The influence of the atmosphere, which was later found to be much less rapid in effect than was at first supposed, was thus avoided. So soon as the tubes were filled, the caps were put in place and the polarization read. To avoid all delay the polariscope was mounted on the launch used by the internal-revenue agent for transportation through the waterways, and the acetylene searchlight furnished the illumination. The rotation in a 10-centimeter tube was: number 5, +28.8; number 6, +33.3. The rotation of the normal weight of sample was calculated from the density determinations, which were made later.

The purity of these samples from the standpoint of the sugar refiner was very high.

From these analyses it is seen that sap of the best quality, as it flows from the flower stalk, has approximately the following composition, stated as grams per 100 cubic centimeters.

Density $\frac{15^{\circ}}{15^{\circ}}$	1.0720
Total solids	³⁴ 18.00
Ash	0.48
Acidity	Trace.
Sucrose	17.00
Reducing sugars	Trace.

An invertase proferment or zymogen, also present in the sap, will be considered later. The large amount of reducing sugars found in the samples which were analyzed immediately shows that the preservatives are not sufficient, or were not employed in sufficient amounts to inhibit the action of the invertase.

FERMENTATION.

(In coöperation with W. B. GONDER and F. AGCAOILI.)

The inversion of the sucrose and the alcoholic, acetic, and other fermentations begin almost immediately after the sap drops from the stem into the bamboo joints ordinarily employed for collecting the sap. These bamboo receptacles are never thoroughly cleaned and no attempt is ever made to sterilize or disinfect them. This condition has given rise to the belief among the distillers that the sap can not be preserved, that the fermentation will always begin immediately, and I have even heard it stated that yeast cells are present in the sap. When the sap is collected in clean vessels,³⁵ it undergoes no change for four or five hours. A white, flocculent precipitate slowly forms, giving the sap a milky

³⁴ Analyses obtained by Ayala and Company showed total solids (degrees Balling) varying from 10.2 to 18.0 per cent.

³⁵ I have usually employed glass bottles.

appearance. Simultaneously with the formation of this precipitate the inversion of the sucrose begins.

Inversion.—The inversion proceeds in practically the same manner in all the palm saps investigated and is undoubtedly due to the formation of an invertase, which appears as a precipitate, from a zymogen which exists in solution in the sap.

The invertase develops, probably under the influence of the atmosphere, after the sap has exuded from the cut stem. The activity of the white precipitate which is not soluble in the sucrose solution corresponds in a measure to the conditions found by Vinson³⁶ in the fruit of the date palm. He identified an insoluble invertase from the cellular structure. In the case of the palm saps an insoluble invertase is precipitated from a clear solution containing no invertase. The chemical composition of the four palm saps investigated is practically identical and the behavior of the invertase from each shows no observed differences worthy of note.

A sample from tree number 5 (see table of analyses) was allowed to stand in the glass bottle in which it was collected, and polarized at various intervals.

TABLE VII.—*Spontaneous inversion of the sap of one tree, collected in a glass vessel (measurements at atmospheric temperature from 24° to 30°).*

Date.	Hour.	Time interval.	Reading in a 10-centimeter tube.	Per cent of inversion, approximate.
		<i>h. m.</i>		
December 14	3. p. m.	0 10	28.8	0.0
Do	4.15 p. m.	1 15	28.8	0.0
Do	7.20 p. m.	4 20	28.8	0.0
Do	8.55 p. m.	5 55	27.6	4.2
Do	10.30 p. m.	7 30	26.5	8.0
December 15	8.30 a. m.	17 30	23.0	20.1
December 16	10.30 a. m.	43 30	1.8	93.7

Samples which are not collected in clean vessels do not show the initial stable period of four or five hours. At 7.15 on the morning of November 21, 1910, fifteen plant stems were washed to free them from molds and other organisms as much as possible, and the bamboo collecting vessels washed clean and placed in position. The sap was allowed to flow forty-

³⁶ *Bot. Gaz.* (1907), **43**, 393. *Journ. Amer. Chem. Soc.* (1908), **30**, 1005: *Journ. Biol. Chem.* (1910), **7**, proceedings XX.

five minutes, at the end of which time the fifteen *tuquils*, containing 1,150 cubic centimeters of tuba, were emptied into a glass bottle and at once taken to the distillery and analyzed. The sample showed a Brix of 10.8 and sucrose of 7.2 per cent. The rate of inversion and alcohol and acid formation were as follows:

TABLE VIII.—*Spontaneous fermentation of the sap collected in bamboo receptacles (composite samples from fifteen plants).*

Time in hours.	Polariza- tion.	Alcohol.	Acidity.	
			cc. $\frac{N}{10}$	As acetic.
0	+ 7.2	0.0	6.0	0.036
1		0.0		
4	+ 6.0			
4.5		0.02	8.0	0.048
6.	+ 4.5		14.0	0.084
8	+ 3.5			
8.5		0.021	30.0	0.180
10	+ 2.5			
10.5			40.0	0.240
23.5	— 1.9		63.0	0.378
24		2.3		
28.5	— 1.4		80.0	0.480
48	0.0			
49			96.0	0.576
49.5				
57		3.1	96.0	0.576

A sample of tuba gathered from *tuquils* as ordinarily cleansed at the distillery gave the following results.

Time interval (hours).	Polarization.
10	—1.00
13	—0.7
15	0.0

The rate of inversion is dependent upon so many factors which are so difficult to eliminate or control that no strictly accurate methods were attempted.

Alcoholic and acetic fermentations.—When the sap is collected according to the native method, common to all the distillery employees and tuba gatherers, the inversion is complete and the alcoholic fermentation well under way, sometimes completed, when the sap arrives at the distillery. It is milky in appearance and covered by a thick layer of foam. Sometimes the acetic acid fermentation has progressed to a considerable extent.

TABLE IX.—*Analyses of tuba collected by native gatherers (samples taken after arrival at the distilleries).*

Sam- ple num- ber.	Density 15° 15°	Solids.	Ash.	Acidity as acetic.	Su- crose.	Reduc- ing sugars.	Alco- hol. ^a	Remarks.
1	1.0070	3.39	0.57	0.81	0.5	0.53	6.40	8 hours after collection from the trees.
2	1.0057	2.41	0.72	1.19	0.0	Trace.	5.65	24 hours after.
3	1.0029	2.05	0.75	0.91	0.0	0.0	6.30	} Collected early in the morning and bottled at 8.30 a. m.
4	1.0075	2.67	0.71	0.94	0.0	0.0	6.20	

^a Analyses obtained by Ayala and Company showed the alcohol content of six samples as received at the distillery to vary from 1.79 to 5.67 per cent. The average was 3.36 per cent.

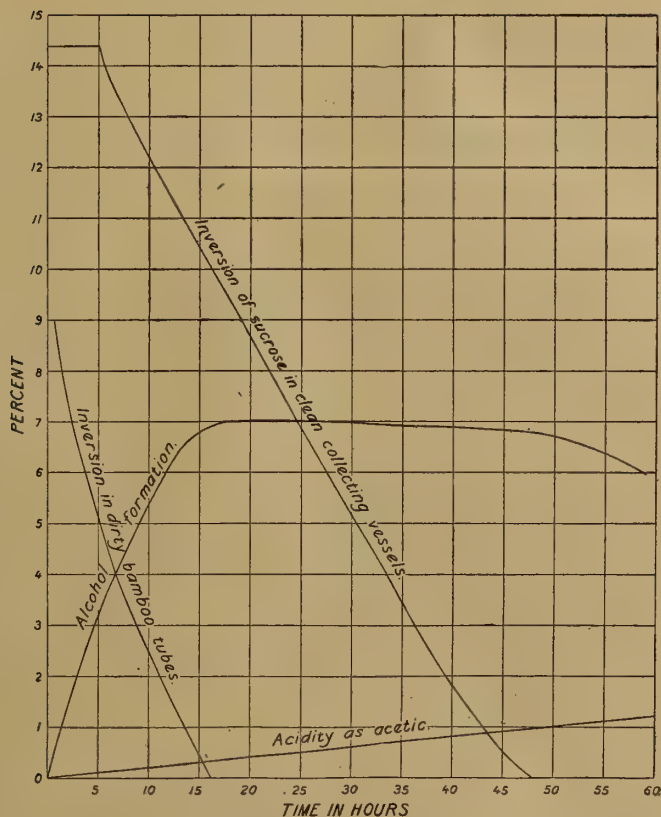
Sample number 1, was collected from a distillery in Bulacan and numbers 2, 3, and 4 from three distilleries in Pangasinan.

The rapidity of the fermentation of a sample collected according to the native methods in dirty bamboo receptacles is shown by the following analyses:

Time in- terval in hours.	Per cent alcohol by vol- ume.	Acidity.	
		cc. $\frac{N}{10}$ in 100 cc.	As acetic.
6	3.70	50	0.300
13	6.40	56	0.336
29	6.85	64	0.384
35.5	6.85	66	0.396
52	6.80	66	0.396
58	5.95	120	0.720

A sample taken in a distillery from a tank which had just been filled with tuba collected ten hours before, showed the following change in alcohol and acid content:

Time in- terval in hours.	Per cent alcohol by vol- ume.	Acidity.	
		Cc. $\frac{N}{10}$	As acetic.
10.0	3.00	-----	-----
12.5	4.00	74	0.444
14.5	4.50	74	0.444
16.5	4.50	74	0.444
31.0	4.50	84	0.504
39.0	4.50	85	0.510
40.0	4.50	85	0.510
57.0	4.50	85	0.510
65.0	4.50	85	0.510
89.0	3.90	-----	-----



TEXT FIG. No. 2.—Spontaneous fermentation of the nipa palm sap.

There is no doubt but that a large proportion of the fermentable sugars is lost through the careless and improper methods employed in the handling of the sap. This will be fully brought out in the section on the distilling. I believe a fair average of sucrose in the sap of the nipa palm is between 14 and 15 per cent. Fourteen per cent sucrose should produce 7.66 per cent by volume of alcohol. This estimate is based on the following calculations:

Theoretically, 14 per cent sucrose will yield 7.5 grams of alcohol $\left(\frac{14}{1.86}\right)$.

Pasteur has shown that 4 to 5 per cent of the sucrose is lost from the alcohol yield because it is split into glycerol, succinic acid, and carbon dioxide, and Harker³⁷ has proved that with molasses the yields of alcohol are about 82 per cent of the theoretical. Assuming that the alcohol yield of the tuba is the same as that of molasses, 6.15 grams of alcohol (7.5×0.82), equivalent to 7.66 per cent by volume, result. I have no doubt but that this figure could be reached in actual practice.

³⁷ *Journ. Soc. Chem. Ind.* (1906), 25, 831.

Internal Revenue Agent Ruge gathered a number of samples of sap in Cagayan which showed after fermentation 7.5 and even higher percentages of alcohol. It is seen that the acidity increases with the per cent of alcohol, until the maximum content of alcohol is reached. During the period of constant alcohol content the acidity remains constant. Upon the decrease in alcohol content the acidity continues to increase.

Other fermentations, the most noticeable of which is the butyric, contribute to the decreased yield of alcohol.

Inhibition of fermentations.—The sap can be preserved by the methods employed with the buri sap³⁸ and the remarks made on this point regarding the buri sap apply equally well to the nipa. The preservation of the sap for sugar making is taken up in the section devoted to that subject.

ALCOHOL PRODUCTION.

Introduction.—Almost 90,000,000 liters of nipa sap were distilled during the fiscal year 1910, producing 9,023,323 proof liters of alcohol. The yields of alcohol obtained from the sap varied from 4.1 to 7.5 per cent. The average for 33 distilleries was 5.6 per cent. The most reliable data which could be obtained are given in Table X.

TABLE X.—*The production of sap from the nipa palm and the amount of alcohol obtained therefrom during the year 1909^a by some of the distilleries in the districts where the production is greatest.*

PAMPANGA AND BULACAN PROVINCES.

Distillery.	Period of nipa tuba production.	Tuba distilled in liters.	Yield of alcohol in proof liters.	Per cent of alcohol obtained from the tuba.
1	July 1, 1909, to February 20, 1910	4,726,389	612,540	6.5
2	do	4,326,942	342,694	5.0
3	do	9,996,052	1,225,516	6.1
4	do	6,527,696	719,394	5.5
5	do	3,362,242	306,312	4.5
6	do	11,807,615	1,271,470	5.4
7	do	7,239,418	965,679	6.7
8	do	5,277,615	675,436	6.4
9	October 10, 1909, to February 28, 1910	8,754,356	805,400	4.7
10	August 21, 1909, to January 31, 1910	1,707,732	224,693	6.6
11	July 1, 1909, to November 30, 1909	208,500	21,713	6.0

^a The data for the entire year of 1909 were not available. Commencing July 1, 1909, records were kept. The periods above recorded include the annual season from July to February, which is the duration of the greatest production of tuba from the nipa palm.

³⁸ See the chapter on the buri palm.

TABLE X.—*The production of sap from the nipa palm, etc.*—Continued.

PANGASINAN PROVINCE.

Distillery.	Period of nipa tuba production.	Tuba distilled in liters.	Yield of alcohol in proof liters.	Per cent of alcohol obtained from the tuba.
1	Year 1909	94,500	9,962	5.1
2	do	387,720	37,430	4.8
3	do	961,400	100,533	4.8
4	do	81,900	8,789	5.4
5	do	538,600	71,545	6.6
6	do	311,670	40,504	6.5
7	do	50,400	5,801	5.8
8	do	89,100	7,236	4.1
9	do	22,400	2,054	4.9
10	do	800	76	4.75
11	do	276,105	29,245	5.3
12	do	266,400	39,958	7.5
13	do	299,250	30,132	5.4
14	do	367,200	40,610	5.5
15	do	28,800	3,038	5.3
16	do	337,920	43,013	6.4
17	do	330,260	31,820	4.8
18	do	146,050	20,711	7.1
19	do	60,060	6,171	5.1
20	do	35,200	3,047	4.3
21	do	44,720	6,829	7.6
22	do	27,600	3,577	6.5

Ninety-seven per cent of the total alcohol produced from nipa sap is obtained from the districts tabulated above.

Twelve provinces from time to time have been engaged in the industry of distilling nipa sap. During the past fiscal year, the business was conducted in only six of these and the total quantity of alcohol produced was the greatest since the American occupation of the Islands. The development of the industry since the enactment of the present Internal Revenue Law is set forth in Table III in the introduction (pp. 102 and 103).

There has been a marked decrease in the number of distilleries operating. When the present Internal Revenue Law was first enforced the large majority of the distilleries were small and very crude. The progressive establishments have crowded out the unprogressive ones and have continually improved and enlarged their plants under the advice and assistance of the Collector of Internal Revenue, whose agents are constantly on the ground.

Conditions in the Province of Pangasinan.—The conditions in the Province of Pangasinan are somewhat typical. The distilleries in that locality use nipa sap almost exclusively as a raw material. It is only

rarely that any sugar-cane products are mixed with the sap. Over one hundred distilleries were operating in this province a few years ago. During the last fiscal year the number was twenty-two and since the data in the preceding table were collected ten have permanently closed. Further reductions in the number operating will take place in the present fiscal year. In the face of this extremely drastic reduction in numbers, the total production of the province has remained practically constant during the past six years. As the methods improve in the surviving distilleries, increased production is to be expected. All of the distilleries in the Province of Pangasinan at this time use copper pot-stills fitted with a goose. The product, a distillate containing from 20 to 30 per cent of alcohol, is all consumed locally.

From the point of view of the collection of the tax on distilled spirits, the rapid decrease in the number of the distilleries is very desirable, provided there is no decrease in the revenue. The number of men engaged in the control and the costs of collecting the tax are reduced, and the opportunities for fraud minimized.

Conditions in the Bulacan-Pampanga district.—In the Provinces of Bulacan and Pampanga, which contain the great nipa district bordering on Manila Bay, the same general decrease in the number of distilleries operating and increase in production is going on. However, here the type of still employed is a great improvement over that in use in Pangasinan and other districts. All of the stills are of the continuous rectifying type; the majority of them produce alcohol varying from 100 to 120 proof, and the remainder manufacture high grade alcohol of 180 to 190 proof. Some molasses, obtained from the neighboring sugar mills, is mixed with the fermenting sap. Control experiments, described later, which embody both types of stills, were run on two of these distilleries.

DISTILLERY METHODS.

Fermentation.—The distilleries receive the tuba in its partially fermented condition, contaminated by many forms of undesirable organisms, and treat it by methods varying from those which are fairly scientific and economical, to the most crude and wasteful means which accompany an almost entire lack of scientific and practical knowledge of the technique of alcohol production. The tuba is first transported to large, wooden fermenting tanks, some of which hold as much as 10,000 liters. A common size is 2.5 meters diameter and 2.5 meters height. Some time ago the Collector of Internal Revenue ordered several sanitary improvements in the distilleries, among the first of which was the abolition of fermentation tanks resting upon the dirt floors. The stench of the fermenting tuba, leaking from rotting wooden tanks into earthen floors

which could not be cleaned, was something which had to be experienced to be appreciated. These tanks are now situated 1 meter above the ground and the floors beneath can be kept in a reasonably sanitary condition. Concrete fermenting tanks are being established in some distilleries. The fermentation is usually allowed to proceed for thirty hours and sometimes longer; in some cases, three days. It has been shown that even the shortest period is too long, much of the alcohol being thus lost through acetic fermentation.³⁹ The distiller recognizes two crude tests for complete fermentation: First, a subsidence of foam, and, second, a fall in the temperature of the liquid.

In some distilleries, especially in those in the first district bordering on sugar-cane lands, the practice of adding molasses to the fermenting sap is very common. This molasses, which usually contains about 60 per cent of fermentable carbohydrates, is sometimes used in amounts equal to that of the tuba. The advantages are threefold; the invertase and alcoholic ferment in the tuba act with great rapidity upon the molasses, providing an easy method for utilization of the latter; the alcoholic content of the liquid is much increased;⁴⁰ and during shortages in the supply of sap, the uninterrupted running of the stills is assured. Some distilleries are enabled to operate during the entire year by employing molasses for a portion of the season.

In some cases, the high acidity of the beer is neutralized by lime made on the spot by burning oyster and other shells. This practice is productive of good results and could advantageously be extended. The fermentation can be checked at the proper moment by the addition of an excess to the liquid in the fermenting vats and thus the tuba can be stored in an unchanged condition awaiting its turn to be run to the stills. Without this expedient much of the alcohol is lost on standing.

No distillery exercises any greater regular control over the fermentation than that described, although some attempts to determine the point of greatest alcohol content by means of the ebullioscope have been observed.

Distillation.—The stills are heated either by direct fires of wood, or mixtures of coal and wood, or by steam coils. Steam is usually supplied from a tubular boiler burning wood or a mixture of coal and wood.

The first distillate from the pot stills is usually collected until it has the alcoholic content demanded by the consumers of the beverage, namely, from 20

³⁹ A distiller, acting upon our advice on this question, shortened the fermentation period to eight hours and immediately obtained increased yields of alcohol.

⁴⁰ This does not always work out as it should. I know of cases where molasses fermented with the tuba has resulted in a liquid containing less alcohol than neighboring tanks of tuba to which no molasses had been added. This was found to be due to improper fermentation. Usually, the fermentation had been allowed to progress until the mixture had more of the characteristics of vinegar than of beer.

to 55 per cent, depending upon the locality. The distillation is further continued until little alcohol is passing over. The pot is then emptied and this second fraction poured back to form a part of the next run. The losses are usually small.

The continuous stills deliver alcohol varying from 50 to 95 per cent. The losses are usually large and can be traced to several different sources. The waste passing out of the stills often contains 1 per cent of alcohol. The plants in Manila are all rectifying stills which are almost entirely employed in the distillation of crude alcohol. Some grain mashes are made. The question of the improvement of distillery methods will be taken up in a subsequent part of this paper.

Transportation of sap and alcohol.—The sap, as has been previously mentioned, is transported to the distilleries in canoes, sometimes in bulk and sometimes in earthen jars. There, it is bailed from the open boats or emptied from the jars into the fermentation tanks sometimes directly after a laborious climb of a flight of steps and sometimes, in the more modern plants, into receiving vessels where it is measured and then pumped by hand or steam to the fermentation vats. In many places the moving of the tuba and alcohol in the distillery is all done by hand by means of the earthen jars, or wooden or glass receptacles. The fermenting tanks are filled by emptying the tuba into them by hand and the fermented liquid is ladled from them to the stills. In some establishments the tuba is transported from the fermentation tanks to the stills by means of iron or bamboo pipes and hand or steam pumps. There is no instance where the wasteful and expensive hand labor of transporting the fermenting sap is entirely done away with.

The methods employed for handling the alcohol are, in general, somewhat better, although many distilleries perform this labor also by hand. Hand or steam pumps and gravity flow are used to transport the alcohol from the condensers or receiving wells to the storage tanks. One of the largest and most economically managed plants in the nipa district employs denatured⁴¹ alcohol to supply power for the electric lighting and pumping machinery. For this purpose two motors, one of 6 and one of 8 horse power, are installed, the former furnishing power in the day and the latter at night when the electric lighting of the distillery and the manager's residence consumes an increased production.

A considerable quantity of the alcohol is transported to Manila in wicker-covered glass demijohns where it is sold for beverages, or to the rectifiers. The best managed plants transport their product in large iron tanks built into the scows or *cascoes* which make the journey across the bay.

An important economic improvement over the present method for conveying the sap from the *nipales* to the distilleries, I believe, could be accomplished by the establishment of pipe lines. The greatest expense involved is that of the pipe. The swamps are of necessity level and the

⁴¹ Law requires industrial alcohol to be denatured.

lines can be laid upon the surface and dropped to the bottom of the shallow waterways. The pumping expense will be very light.

The advantages to be gained are the great saving of time and labor required in the transportation, reduction in losses from evaporation and leakage, the opening up of producing areas which are now inaccessible, and the consolidation of small isolated plants into large central distilleries. At present, the greater proportion of the tuba gatherer's time is occupied in paddling the canoes to and from the distillery and in unloading. On the establishment of a pipe line he could live on his allotted area with his family and devote his entire time to the care of the plants and the gathering of the sap. A saving of no mean importance would be the elimination of the expense of making new waterways and dredging old ones.

The only objections which have been advanced to me are, first, the fact that the tuba gatherer is paid so much for the tuba which he delivers at the distillery so that the transportation is no expense to the distiller, and, second, that the acids forming in the fermenting sap will rapidly destroy the pipes. The first objection is an economic fallacy and the second I believe can be met by lining the pipes with the proper resisting material. I have the hope that some distiller will give this suggestion a trial by the establishment in the near future of a small pipe line.

Efficiency of distilleries.—Two distilleries in the first district (Bulacan-Pampanga) one producing low-grade alcohol, the other, highly rectified spirits, both employing continuous stills, were selected as typical for investigations of efficiency. Analyses of the fermented sap entering the stills, the alcohol and the waste were made at regular intervals throughout a run and an attempt to locate the losses was made.

CONTROL TESTS.

By W. B. GONDER and F. AGCAOILI.

Control test No. 1, November 19, 1910.—The distillery is located at Hagonoy. The plant consists of two steam-heated stills with accompanying steam boiler, steam pumps, fermenting vats and storage tanks for alcohol, and produces alcohol ranging from 96 to 106 proof.

Before starting the test, the tuba supply was stopped and all supply tanks connected with the stills as well as the stills themselves were emptied and all alcohol in the reservoirs and pipes was pumped to the storage tank.

At 8 a. m. the tuba was turned on, the machine started and run continuously for eight hours, the tuba supply being turned off at 4 p. m.

Samples of tuba, alcohol produced, and waste, were taken every hour and analyzed for the alcohol content and acidity. The polarization of the tuba was also noted.

TABLE XI.—*Analyses of tuba entering the still and waste in control test No. 1, at a distillery in Hagonoy.*

Time.	Fermented tuba.					Waste.			
	Temperature.	Density.	Acidity, cc. 0.1 N.	Polarization.	Per cent alcohol by volume.	Polarization.	Temperature at exit.	Acidity, cc. 0.1 N.	Alcohol.
	°C.						°C.		
8 a. m. -----	28	1.0004	86	+0.4	3.96	-----	98	74	Varies from 0.1 to 0.93 per cent.
9 a. m. -----	28	1.0003	90	+0.3	3.57	-----	98	88	
10 a. m. -----	28	1.0004	90	+0.1	5.32	-----	98	80	
11 a. m. -----	28	1.0005	88	0.0	3.96	-----	98	80	
12 a. m. -----	29	1.0006	90	0.0	4.53	-----	98	84	
1 p. m. -----	29	1.0004	88	0.0	4.07	-----	98	84	
2 p. m. -----	29	1.0000	88	+0.1	4.22	-----	98	88	
3 p. m. -----	29	1.0004	90	+0.1	4.45	-----	98	80	
4 p. m. -----	29	1.0000	94	+0.1	4.84	-----	98	90	
Average -----	28.55	-----	89.3	+0.1	4.32	-0.02	98	84.1	-----

Distilled during test, liters	29,974
Volume of alcohol produced, liters	3,280
Temperature of alcohol °C	28.55
Per cent alcohol by volume	32.98
Average acidity, cc. 0.1 N.	11.9
Liters of alcohol (absolute) produced	1,081.74
Per cent alcohol produced on tuba distilled	3.6
Liters of absolute alcohol possible of recovery	1,294.83
Liters of absolute alcohol lost	213.14
Per cent of alcohol in the tuba lost	0.71
Per cent of alcohol lost	16.46
Efficiency during the run, per cent	83.54

This distillery always added a quantity of molasses to its tuba. This small yield of alcohol indicates that the fermentation had passed its maximum, and the alcohol content was undoubtedly on the decrease. In this instance the distillers had more tuba on hand than they could handle in an efficient manner. However, this efficiency test of the distilling plant was not influenced by this fact.

Control test No. 2.—This test was made at San Esteban, in the same way as No. 1, but over a period of six hours, because of lack of tuba. In addition to the four steam-heated machines which were in constant operation, the plant also contains two direct-heat stills used only when large quantities of tuba are on hand.

The results of this test are as follows:

TABLE XII.—Analyses of tuba entering the still and waste in control test No. 2, at the San Esteban distillery.

Time.	Fermented tuba.					Waste.			
	Temperature.	Density.	Acidity, cc. 0.1 N.	Polarization.	Per cent alcohol by volume.	Density.	Temperature.	Acidity, cc. 0.1 N.	Alcohol.
	°C.						°C.		
10.30 a. m.-----	25	1.0024	70	0.0	3.76	1.0080	98	40	Varies from less than 0.1 to 0.33 per cent.
11.30 a. m.-----	25	1.0026	70	0.0	3.92	1.0086	98	60	
12.30 a. m.-----	25	1.0026	118	0.0	5.15	1.0074	98	44	
1.30 p. m.-----	25	1.0020	100	0.0	5.15	1.0070	98	45	
2.30 p. m.-----	25	1.0014	81	0.0	5.31	1.0084	98	32	
3.30 p. m.-----	25	1.0040	81	0.0	5.15	1.0077	98	58	
4.30 p. m.-----	25	1.0036	85	0.0	5.15	1.0096	98	57	
Average -----	25		86	0.0	4.79		98	52	

Volume of raw tuba distilled, liters	48,327
Average of polarization of waste	0.0
	Low grade. High grade.
Alcohol produced, proof liters	1,125 1,410
Per cent alcohol by volume	71.92 87.67
Average acidity, cc. 0.1 N.	3.0 1.0
Liters of absolute alcohol produced	2,045.25
Per cent alcohol produced in tuba distillate	4.24
Liters of absolute alcohol possible of recovery	2,314.87
Liters of absolute alcohol lost	269.63
Per cent of alcohol in tuba lost	0.55
Per cent of alcohol lost	11.65
Efficiency of plant, per cent	88.35

None of the distilled tuba contained any molasses and tests made in the Manila laboratory proved the absence of invert sugar, thus showing complete fermentation.

The waste from each of the four machines is run through a final condenser and the vapors arising from its high temperature are condensed and returned to the tuba tank for redistillation. An average of six tests made upon these condensed vapors gave 0.75 per cent of alcohol by volume.

Another practice observed at San Esteban is the neutralization of the acids in the tuba with lime. The effect may be seen in the lower acidity of the San Esteban product as compared to that of Hagonoy, where no attempt was made to neutralize.

Whether or not neutralization has any effect upon minimizing the loss in the waste is a matter for conjecture. The fact remains that much

less alcohol passes out in the waste at San Esteban than at Hagonoy. The low-grade alcohol is usually rectified at Manila distilleries, while the high grade has a direct market.

Losses.—The losses of alcohol, amounting to 16.46 per cent in the first run and 11.65 per cent in the second, of the total amounts possible of recovery, are to be attributed to a number of causes. The waste from the still, at times in the Hagonoy plant, was found to contain as much as 0.93 per cent and in San Esteban plant 0.33 per cent. The amount in the waste of the stills at the San Esteban distillery is usually less than 0.33 per cent. Other sources of loss are due to evaporation and leakage. Since running these tests, several improvements have been installed, to minimize these losses.

SUGGESTIONS FOR IMPROVEMENT.

The following methods are all susceptible of improvement: Transportation of sap from *nipales* to distillery and at the distillery, control of the fermentation, and, in some cases, the construction and operation of the stills and pumping machinery. The greatest loss at this time, and one which is experienced in all of the distilleries, is through the failure to obtain, even approximately, the alcohol yield to be expected from the sucrose content of the sap. This loss is more than 50 per cent at many distilleries. Even in the best managed distilleries little or no attempt is made to control the fermentation. The tuba, when received, may have undergone changes varying from only partial inversion of the sucrose to a stage where the acetic acid fermentation is well under way, depending upon the length of time which has elapsed since the sap flowed from the plant. The receptacles in which the tuba is handled, especially the dirty bamboo joints, introduce, in all cases, undesirable ferments. The great effort which the Bureau of Internal Revenue is making to introduce cleanliness and cleanly methods is deserving of great praise and more encouragement.

COSTS.

The raw material.—By long usage the *tinaja*, an earthen jar for transporting sap, has become the standard of measure in the nipa districts. Of course such a vessel varies in size and many of the distillers have very little idea of its capacity. Ten distillers variously estimated their *tinajas* at from 25 to 90 liters capacity. I measured two at different establishments in the Province of Pangasinan and found their capacities to be 50 and 63 liters. In the Bulacan-Pampanga district, the *tinajas* are smaller and estimated at 32 to 36 liters. Tuba is purchased with the peso (fifty cents United States currency) as the unit of value and the *tinaja* the unit of capacity.

The price paid for the sap of the nipa palm varies in different years

and in the seasons of the year. In Pangasinan it is from 3 to 11 pesos for 12 *tinajas*.

This is at the rate of 0.020 (the highest price and the smallest *tinaja*) to 0.003 peso (the lowest price and the largest *tinaja*) per liter, for the raw material. A fair, estimated average is 0.006 peso. The great variations in price are due to fluctuations in the demand for the distilled beverage at the different distilleries, rivalry among their owners, and to seasonal and yearly variations in the supply of sap. The latter is one of the most important factors controlling the price. In the Bulacan-Pampanga district the distilleries are larger, equipped with better machinery and in general are better managed, the result being that the industry is on a more stable basis and the fluctuations in the price of tuba less violent. The price of 100 *tinajas*, from 3,000 to 3,600 liters, fluctuates between 12 to 18 pesos. Thus the raw material varies from 0.003 to 0.006 peso per liter.

There is no doubt but that much sap is purchased at lower figures by some shrewd buyers. The Chinese, who own and operate several distilleries, excel in this respect. The difficulties attending the process of obtaining accurate information can not be appreciated by one who has not dealt with Filipinos and other Orientals.

The measure of the volume of the tuba delivered at the distillery is an unsatisfactory method for arriving at the price to be paid the gatherers, as the tendency to adulterate with water is too strong to be resisted. In some of the best managed plants, the alcohol in the tuba is determined by means of the ebullioscope, and the sugar estimated by determining the density. Some distilleries purchase tuba entirely upon its alcohol and sugar content. Even when the establishment owns the *nipales*, this check is necessary, for the tuba gatherers are usually paid on the basis of the volume of tuba delivered and are not compensated by a daily wage.

The alcoholic production from nipa sap should be above 6 per cent of the tuba, and I have no doubt that under favorable conditions it would be above 7 per cent.

Taking a low average value, 6.5 per cent alcohol, or 13 proof, the purchase price of the raw material is equivalent to a cost of 0.0415 to 0.0830 peso per liter for 90 per cent (180 proof) alcohol.

These estimates are made upon the raw material delivered at the distillery and show nipa sap to be the cheapest source of alcohol in the world. However, I do not believe this to be the case at all times. Three exceptions are to be noted. There are occasions when molasses at the sugar mill may produce cheaper alcohol, although I do not believe this to be generally the case. Cassava in the Philippine Islands, I am informed, can be grown at such prices that the raw material for 1 liter of 180 proof spirits will cost as little as 0.04 peso or perhaps less. The third possible exception is the new process for the utilization of wood wastes or sawdust.

In the case of nipa sap it is to be remembered that no processes of puri-

fication, pulping, etc., are necessary as with grains, cassava, and similar sources of alcohol. Small storage capacity and fermenting vats are necessary, since the fermentation is complete in from six to ten hours and the material is ready for the stills. At the present time, I see no reason for placing the nipa sap in any other than the first place in the order of low cost.

Cost of distillation.—The actual cost of distillation during the runs made at the two distilleries and described under control tests Nos. 1 and 2 can be figured from the following data:

TABLE XIII.—*Cost of the alcohol produced during tests of distilleries.*

	Control test No. 1.		Control test No. 2.	
	Liters.	Pesos.	Liters.	Pesos.
Tuba distilled	29,794		48,327	
Cost of tuba at 0.00388 peso per liter		115.60		187.73
Molasses mixed with the tuba	189			
Cost of molasses		11.60		
Salaries		10.00		10.00
Fuel *		10.00		10.00
Lime		0.00		2.00
Alcohol calculated as 95 per cent	1,139		2,153	
Total cost (except interest on investment and administration)		147.20		209.73
Cost of alcohol per liter (calculated to 95 per cent)		0.129		0.097

* The average Australian coal employed in the Philippines has a heating value of 6,600 calories and costs about 12 pesos per metric ton. On this basis the fuel for the two runs costs 3.78 pesos and 6.10 pesos, respectively.

Since the losses of alcohol during fermentation, distillation, and transportation were undoubtedly large, I do not see anything in these figures which will necessitate a modification of the statement that the nipa sap takes first rank in order of low cost as a source for alcohol.

The current selling prices in Manila of the various grades of rectified alcohol are about as follows:

Per cent.	Selling standard, °Cartier.	Price per liter in pesos.
97.9	42	0.72
95.6	40	0.66
89.8	36	0.62

The tax included in these figures is 0.25 peso per proof liter.

	Pesos.
Denatured tax free 42° Cartier	0.19
Denatured tax free 40° Cartier	0.16

The income derived from the nipa swamps and the compensation of the laborers.—Where the owner of the *nipales* does not personally gather

or superintend the gathering of the tuba, this work is turned over to laborers, to each of whom are apportioned about 700 to 1,000 producing plants, or two men to about 1 hectare of nipa swamp. These men receive one-half of the tuba, the owner of the *nipal* taking the other half. The yield of tuba from this area, if well managed, will average 480 liters per day for six months of the year. Therefore, the owner of the swamp and the laborers receive an equal income, which is one-half the value of 86,000 liters of sap. The owner, therefore, secures about 129 pesos per hectare per annum and the two laborers receive the same amount, depending upon the price of the tuba.

In one locality I am informed that it is customary for the best laborers to deliver 250 *tinajas*, or 9,000 liters of sap at the distillery each week, for which 17.50 pesos are paid, at the rate of 7 pesos per 100 *tinajas*. For a period of one-half year such a laborer would earn 455 pesos, but I believe this rate is kept up for only about three months. This places the yearly earnings of the exceptional man at about 230 pesos. The gathering of the tuba from the flowing plants is not the only work, for, throughout the season, additional plants must continually be treated to bring them into production.

These estimates are subject to variations due to fluctuations in the price of tuba and also to various standards existing in different nipa districts and to different methods practiced by the owners. It is also to be remembered that on the estates where the tuba season is six months in duration the work of looking after the plants, building waterways, and general care of the estate goes on throughout the year and the tuba gatherer is required to carry on these duties even though his income has ceased through the nonproducing of the grove. Moreover, on some estates he is required to buy, or is charged with the earthen jars, *tinajas*, used for transporting the tuba and the hollow bamboo joints employed for the collection. This latter item is by no means small, since over 700 receptacles of this character are required per hectare, and the loss through breakage and decay is a factor to be considered. Other estates and distilleries furnish the tuba gatherers with boats, earthen jars, and bamboo joints, hire laborers to build and repair the waterways and canals, and do not make a charge against the tuba gatherers for these items.

In some cases, in order to hold the workmen on the *nipales* through the months when there is no tuba to be gathered and the worker's income has ceased, it is customary to allot to each family a plot of ground upon which they may grow products, principally *bacao*, a good firewood, which are bought by the distillery. Medical attendance, medicines, and cedulas (poll tax 2 pesos) are also furnished the workmen. They, in return, are required to care for the *nipales*, clear the land, and build waterways during the slack season.

In view of the fact that the work of the tuba gatherer is light and well suited to the native temperament in so much as it is a life on the water in his canoe with the hours of labor more or less regulated to suit

his inclinations, the rate of wage might be considered in most cases fair for six months' labor. Where the tuba gatherer furnishes the utensils to carry on the work and builds and repairs the waterways, it is undoubtedly low as a total annual rate and, in many cases, is a bare living.

Since he receives the price of one-half of the tuba, and is subject to no expense in gathering and very little for maintenance, the owner of the land is in receipt of a large income from his swamp. A good nipa swamp properly cultivated and managed is a very valuable property. I am informed that sales at as high as 1,500 pesos per hectare have been made.

VINEGAR.

Analyses by W. C. HOLMES and F. AGCAOILI.

Judging from the sucrose content of nipa sap, it is evident that a vinegar of good quality can be manufactured from the tuba. Three samples of vinegar made from nipa tuba were obtained in the native markets in Manila. The analyses are as follows:

TABLE XIV.—*Analyses of nipa vinegar.*

Components.	Number 68758.	Number 68759.	Number 68760.
Total solids.....	1.35	2.03	1.54
Ash.....	0.66	0.72	0.72
P ₂ O ₅		0.03	
Acetic acid.....	2.17	3.23	3.03
Alcohol.....		1.20	3.03

The native methods of manufacture are so crude that a good quality of vinegar could not be expected to result therefrom.

SUGAR.

The composition of the sap led me to the belief that it could profitably be employed as a source of sugar. The sucrose content of all of the plants which I have investigated ranged from 12.5 to 17.0 per cent and I believe a fair average lies between 14 and 15 per cent. The purity is approximately 90 per cent.

Collection of sap.—An efficient method for preserving the sap is the first essential. Lime answers the requirement perfectly. Sap collected in the bamboo receptacles ordinarily employed by the natives remained unchanged for a longer period than ten days when the receptacles, before placing upon the plant stems, were coated on the inside with milk of lime by dipping into a rather thick mixture of lime and water. Since this preservative enables the sap to be collected and transported to the central refinery in an unchanged condition, the principal

difficulties connected with such an industry are met, for the sap in its composition so nearly resembles cane juice that no special changes are necessary in the process of refining.

Sugar-boiling experiment.—On December 14, 1910, at 6 o'clock in the evening, twenty new bamboo joints (*tuquils*) were coated on the inside with a thick mixture of lime and water and immediately placed in position to catch the sap from as many nipa palms. The lime employed was manufactured at the distillery by burning oyster and other shells. At 6 the next morning, the sap which had flowed during the twelve hours was collected in a glass demijohn and transported to Manila to the laboratory. It was filtered twenty-eight hours after collection, and the clear filtrate measured 15 liters. The analysis is given in column I of Table XV.

Four liters of this liquid were heated to boiling in a large porcelain evaporating dish and carbon dioxide run in until the alkalinity was reduced to 0.10 gram calcium oxide for 100 cubic centimeters of solution. The solution was then filtered and analyzed. See column II, Table XV.

The process of evaporation was then continued and the alkalinity further reduced with sulphur dioxide to 0.011 gram calcium oxide for 100 cubic centimeters of liquid. The solution was again filtered and analyzed. See column III, Table XV. This solution contained, according to the analysis, 236 grams of sucrose.

On boiling down to a massecuite and cooling, crystals of good grain were obtained. These, on drying in a hand centrifuge and finally in an air bath at about 90°, weighed 157 grams, were pure white, and polarized at 96.8 per cent.

The molasses and washings were boiled down to a second massecuite and treated in the same way. A yield of 79 grams of very light yellow sugar polarizing at 93.8 was obtained. The second molasses was light yellow, measured 20 cubic centimeters and polarized at 58.6. A third sugar could easily have been crystallized from it if the volume had been sufficient. The losses were entirely due to the numerous samples taken for analysis during the course of the work and to the handling of small quantities of material in the centrifugal machine, which was much too large for the samples.

Ten days later, on December 24, 1910, a second portion of the same raw material was treated in practically the same manner. The original analysis is given in column IV, Table XV, the analysis after the carbon dioxide treatment in column V, and after the sulphur dioxide treatment in column VI. Two liters of this solution, containing theoretically 276 grams of sucrose, yielded 210 grams of first sugar, which was almost pure white and polarized at 96.8. The quantity of molasses was too small to handle successfully in the apparatus, so no further attempt was made to refine it, although with larger quantities it could easily be handled. The analyses are given in the following table:

TABLE XV.—*Analyses of solution of nipa sap during the process of purification for sugar making.*

	First run.			Second run.		
	I.	II.	III.	IV.	V.	VI.
Density $\frac{15^{\circ}}{15^{\circ}}$ -----	1.0615	1.0570	1.0620	1.0619	1.0615	1.0636
Solids by table -----	15.0	14.0	15.2	15.2	15.1	15.5
Polarization -----	10.2	12.2	13.4	10.2	12.2	13.8
Alkalinity:						
cc. $\frac{N}{10}$ per 100 cc. -----	450	36	4.0	461	111	3.0
g. CaO per 100 cc -----	1.26	0.10	0.011	1.29	0.311	.008
Purity -----	67.3	87.1	88.2	67.1	80.8	90
Color -----	Brown.	Yellow.	Pale straw.	Brown.	Yellow.	Very pale straw.

The refining of this sap will require the ordinary equipment of a sugar mill with the exception of the crushers, namely, a lime kiln to furnish both the lime and the carbon dioxide, clarification, sulphur, and concentrating apparatus, filter presses, centrifuges, steam generating plant, dynamos, and motors. A great saving over the cane will be the omission of the crushers. The nipa districts are well suited for cheap transportation of fuel, limestone, and the various supplies through the waterways, and for the shipment of the product.

Estimates of production.—The investigations of a number of individual trees, previously described, show that a seasonal production of 43 liters of sap is about the average.

On the basis of 2,000 trees per hectare the sap-yield is 86,000 liters per annum per hectare. Estimating 14 per cent sucrose in the sap or, to be on the side of conservatism, 12 per cent recoverable sugar, the yield per hectare will be 10,428 kilos of 96 per cent sugar valued at 0.16 peso (subject to market fluctuation) per kilo, at 1,668.48 pesos. A hundred-ton sugar mill would probably be kept running 180 days of the year on the product of 750 to 1,000 hectares. The actual figure derived from calculation is 745 hectares.

Since the cost of refining will probably be less than that for cane⁴² and since sugar is an expensive raw material for the manufacturer of alcohol, I am strongly of the opinion that more profit is to be made from the nipa lands through the establishment of sugar refineries than distilleries.

⁴² While many cost factors are in favor of the refining of the nipa sap there is one in favor of the cane, namely, the item of fuel. The bagasse is usually sufficient to supply fuel for the cane mill, while in the case of the palm sap there is no by-product which can be used for fuel.

I fully realize that great claims which have never been realized have been made for the profits to be derived from the use of other palms, *Arenga saccharifera* and the *Caryota urens*, in Java and India, for sugar production on a commercial scale attractive to the investment of European and American capital. However, in the case of the nipa, many of the difficulties encountered with the other palms do not exist. Some of the points of especial advantage to the *nipales* are as follows: The swamps already exist in a state ready to bring them into active production merely by thinning, or, in the case of the swamps already employed in the alcohol industry, this work is already well under way; many large areas are not now put to any use and are to be had for a small investment; the plants reproduce themselves and it is probable that each plant is capable of producing continuously for fifty years; the flower stems are close to the ground and the work of gathering the sap is quickly and easily performed; the producing plants grow very close together and the production per hectare is large; transportation of the sap is cheaply accomplished through the numerous waterways.

Before concluding, I must point out that while these estimates are the result of accurate laboratory and field investigations, they must be substantiated by experimental work on a small factory scale. I sincerely trust that some one will be found willing to make the initial investment to test these figures. If no unforeseen difficulty is encountered, I believe splendid returns will accrue.

THE FRUIT OF THE NIPA PALM.

The seed (see Plates III and IV), when soft and jelly-like, is eaten raw or after preserving with sugar sirup. It is white when removed from the carpel and turns brown on exposure to the air. The flavor is agreeable, resembling that of meat of the coconut.

An average size fruit weighed 9,541 grams, and consisted of 8,960 grams of husks and stems and 575 grams or 6.1 per cent of edible seeds. An incomplete analysis of the seeds is as follows:

	Per cent.
Solids	20.75
Ash	1.25
Protein (N×6.25)	2.64
Reducing sugars	28
Fat	1.79
Crude fiber	3.30
Sucrose	None.
Starch	None.
Undetermined	11.69

ILLUSTRATIONS.

PLATE I.

- FIG. 1. View from top of San Esteban distillery. Nipa swamps as far as the eye can reach. (Photograph by Martin.)
 2. Uncultivated nipa swamp. Legaspi, Albay Province. (Photograph by Martin.)

PLATE II.

- Cultivated nipa swamp. Bulacan. (Photograph by Martin.)

PLATE III.

- FIG. 1. Collecting the nipa sap. Showing a native collector and two bamboo joints (*tuquils*) in position to receive the sap. (Photograph by Martin.)
 2. Nipa palms in fruit.

PLATE IV.

- FIG. 1. Nipa carpel.
 2. Opened carpel showing seed.

PLATE V.

- Unloading sap in *tinajas* from the canoes in which it is transported to the distillery. (Photograph by Martin.)

PLATE VI.

- Panoramic view of the plant of Ayala and Company's distillery at San Esteban, Pampanga Province. From right to left are the storehouse for the nipa sap, the distillery, the manager's residence, and the storehouse for alcohol. The pipe line connecting the latter with the distillery can be seen supported on poles and appears in the distance like a telegraph wire. (Photograph by Martin.)

PLATE VII.

- FIG. 1. Interior of distillery in Bulacan Province. (Photograph by Martin.)
 2. Rectifying column in "La Clementina" distillery, Manila. Owned by Compañía General de Tabacos de Filipinas. (Photograph by Martin.)

PLATE VIII.

- FIG. 1. Carabao delivery cart in streets of Manila. Loaded with 50 arrobas (800 liters) of anisado. (Photograph by Martin.)
 2. Demijohns containing 2,401 arrobas (38,416 liters) of anisado made from nipa alcohol, ready for shipment. (Photograph by Martin.)

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FIG. 1.



Photograph by Martin.

FIG. 2.



Photograph by Martin.

PLATE II.



Photograph by Martin. FIG. 1.

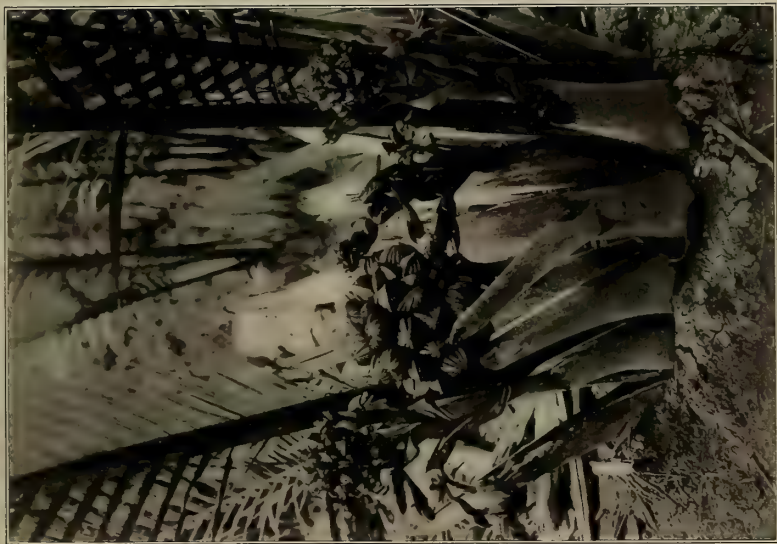


FIG. 2.

PLATE III.



FIG. 1.

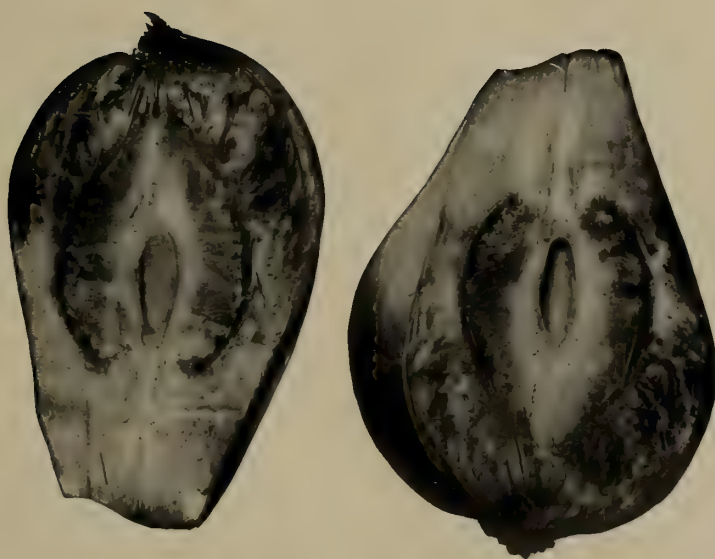
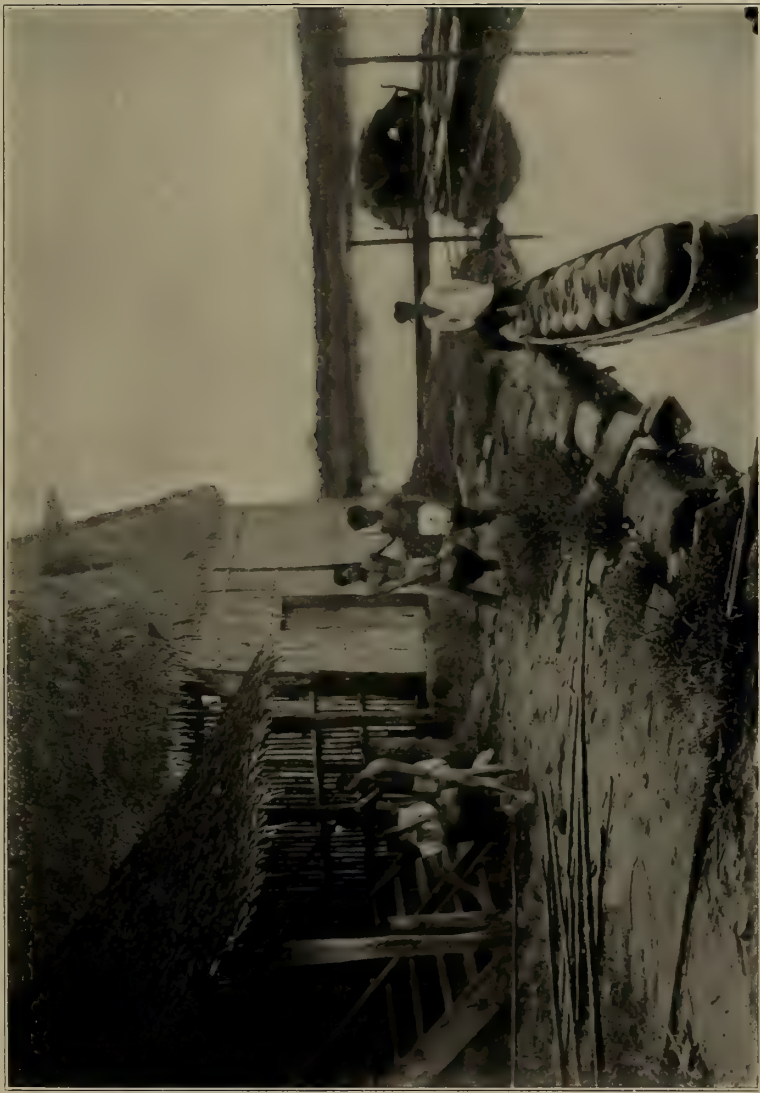


FIG. 2.

PLATE IV.



Photograph by Martin.

PLATE V.



Photograph by Martin.

PLATE VI.



Photograph by Martin.

FIG. 1.

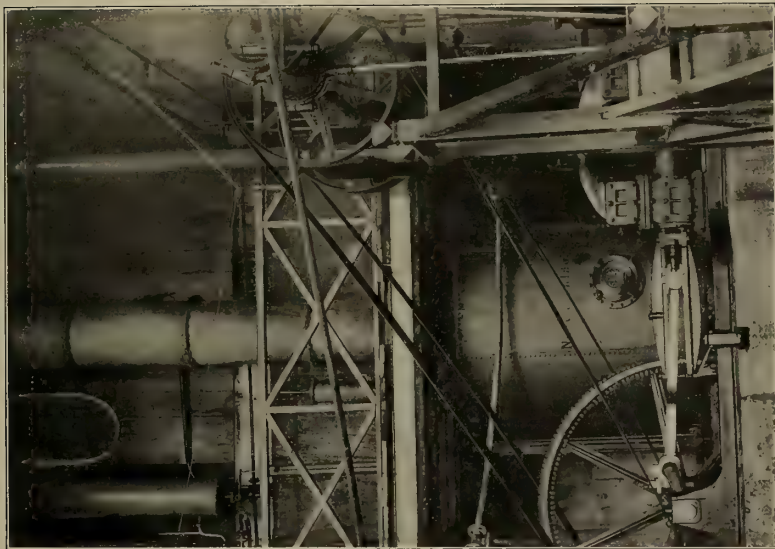


FIG. 2.



FIG. 1.



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FIG. 2.

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THE ALCOHOL INDUSTRY OF THE PHILIPPINE ISLANDS. PART I. (Concluded.)

By H. D. GIBBS.

(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

THE COCONUT PALM.

Cocos nucifera Linn.

CONTENTS.

COMMERCIAL IMPORTANCE.

DISTRIBUTION.

USES.

THE SAP.

Tapping the palm.

The yield of sap. Tables XVII, XVIII, and XIX.

The composition of the sap. Table XX.

The utilization of the sap.

Costs. Table XXI.

The sap of the coconut palm as a source of sugar. Table XXII.

Vinegar. Table XXIII.

COMMERCIAL IMPORTANCE.

Commercially, the coconut is the most important of all the palms. The production of copra for the manufacture of coconut oil is an industry which is growing, and the supply of oil seems to be inadequate

to keep pace with the constantly rising demand, the result being a tendency toward higher prices. In the Philippine Islands, the preparation of copra is rapidly gaining both in local and world-wide importance. The exports are increasing and the areas planted in coconut palms are being greatly augmented from year to year. The exports are shown in the following table:

TABLE XVI.—*The exports of copra and coconut oil⁴³ and their values for the last ten years, 1900 to 1910.^a*

Year.	Copra.		Coconut oil.	
	Kilograms.	Value (U. S. currency).	Liters.	Value (U. S. currency).
1900.....	37,180,000	\$1,690,897		
1901.....	52,639,717	2,648,305	174	\$115
1902.....	19,686,785	1,001,656	238	14
1903.....	97,629,523	4,472,679	3,130	355
1904.....	54,129,606	2,527,019	824	73
1905.....	37,103,065	2,094,652		
1906.....	66,157,994	4,043,115	400,500	39,583
1907.....	49,081,979	4,053,193	413,000	50,662
1908.....	76,419,677	5,461,680	^b 2,915,114	263,069
1909.....	105,564,781	6,657,740	^b 1,484,170	157,916
1910.....	116,374,851	9,153,951		

^a Data from reports of the Collector of Customs.

^b Quantity in kilograms.

The Philippine Islands are rapidly becoming the greatest producers of copra in the world, the greater proportion of the product being exported to France. At the present time practically no oil is pressed in the Islands. The little that is manufactured is prepared by crude native methods and consumed locally.

DISTRIBUTION.

Although the coconut palm is distributed throughout the Archipelago, the majority of the trees are in the Provinces of Laguna and Tayabas. A distribution map is reproduced on page 149. The location of the coconut areas of the Philippines was largely determined from industrial maps submitted by division superintendents to the Philippine School of Commerce. These showed the distribution of the various agricultural products of the Philippines for each province. The density of the areas was determined in terms of "many" and "few" from the industrial schedules sent out by the Bureau of Education in the year 1910.

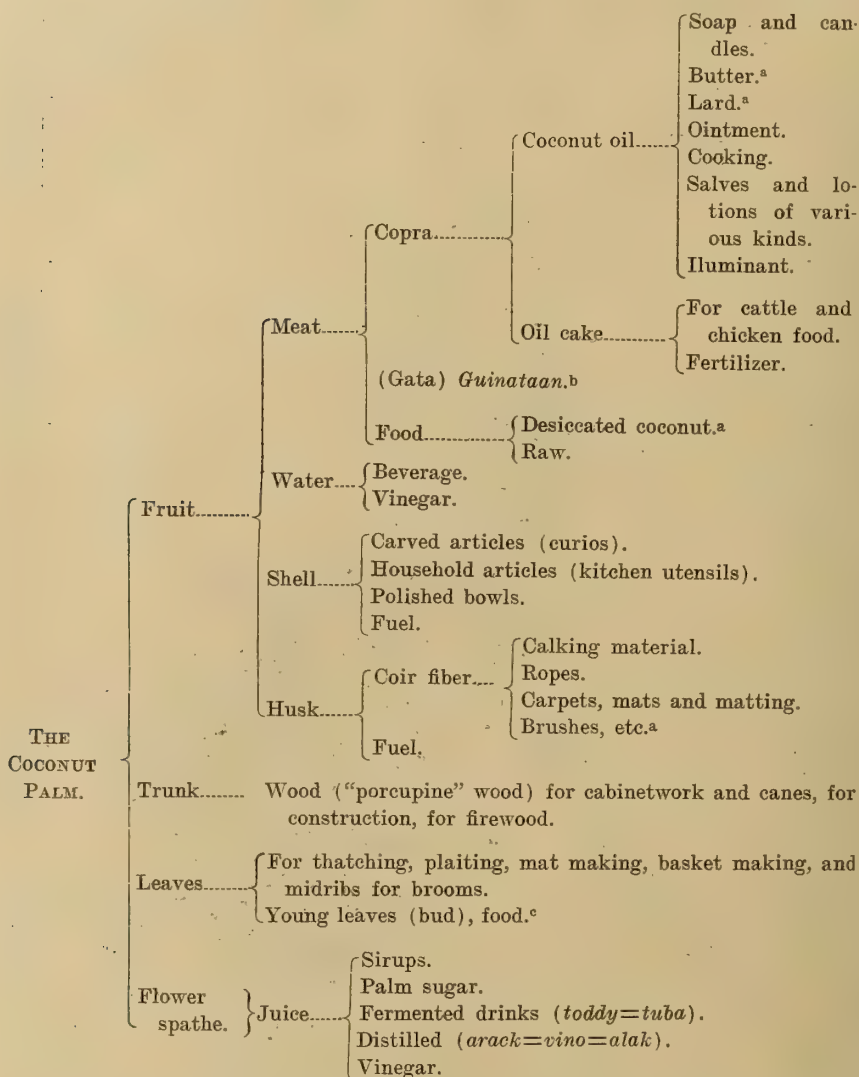
⁴³ The only modern coconut-oil factory was destroyed by fire in 1909.



Map No. 2.

USES.

The native puts the coconut to many uses in his daily economy. These are tabulated as follows:



^a A number of these possibilities are not taken advantage of in the Philippines.

^b A food product made from the juice or milk expressed from the fresh meat. The name is *Tagalog*.

^c The young stem tissues are also eaten.

THE SAP.

In the Philippine Islands, large numbers of coconut palms are utilized exclusively for the production of sap which is made into an intoxicating beverage, called *vino de coco* (wine of coco) which, in spite of the crude methods of native manufacture, has much to recommend it both to native and foreign taste. The alcoholic strength varies from 20 to 50 per cent; the flavor is rather agreeable. The effect is rapid and in many cases accompanied by the usual disagreeable after effects of whisky or alcohol, sometimes in an aggravated form. *Vino de coco* is misnamed, for it is a distillate of the nature of brandy and not a wine.

Beverages of similar character, most commonly called *arrak*, are made in India, Malaysia, and many islands of the Pacific Ocean where coconut palms abound.

The natives of Guam and other places use the sap of the coconut palm as a beverage, sweet, fermented and distilled. Dampier⁴⁴ in 1686 found that:

"Beside the Liquor or Water in the Fruit, there is also a sort of Wine drawn from the Tree called Toddy, which looks like Whey. It is sweet and very pleasant, but it is to be drunk within 24 hours after it is drawn, for afterwards it grows sowre. Those that have a great many Trees, draw a Spirit from the sowre Wine, called Arack. Arack is distill'd also from Rice, and other things in the East-Indies; but none is so much esteemed for making Punch as this sort, made of Toddy, or the sap of the Coco-nut Tree, for it makes most delicate Punch; but it must have a dash of Brandy to hearten it, because this Arack is not strong enough to make good Punch of it self. This sort of Liquor is chiefly used about Goa; and therefore it has the Name of Goa Arack. The way of drawing the Toddy from the Tree, is by cutting the top of a Branch that would bear Nuts; but before it has any Fruit; and from thence the Liquor which was to feed its Fruit, distils into the Hole of a Callabash that is hung upon it.

"This Branch continues running almost as long as the Fruit would have been growing, and then it dries away. The Tree hath usually 3 fruitful Branches, which if they be all tapp'd thus, then the Tree bears no Fruit that year; but if one or two only be tapp'd, the other will bear Fruit all the while. The Liquor which is thus drawn is emptied out of the Callabash, duly Morning and Evening, so long as it continues running, and is sold every Morning and Evening in most Towns in the East-Indies, and great gains is produced from it even this way; but those that distil it and make Arack, reap the greatest profit. There is also great profit made of the Fruit, both of the Nut and of the Shell."

He also states⁴⁵ that the greatest use the inhabitants of the Island of Nicobar make of their coco trees is to draw toddy from them, of which they are very fond.

Safford⁴⁶ states that:

"The custom of making a fermented drink from the sap of the coconut palm, of which the Polynesians are ignorant, was introduced into Guam by the Filipinos

⁴⁴ Voyages, London (1906), 1, 304.

⁴⁵ *Ibid.*, 466.

⁴⁶ *Cont. U. S. Nat. Herb.* (1905), 9, 237.

brought by the Spaniards to assist in reducing the natives. Before the arrival of the Spaniards the aborigines had no intoxicating drink." He also states that:

"From the fermented liquor a kind of rum is distilled, called 'aguayente' (aguardiente) by the natives of Guam and 'arak' in the East Indies. The distilling of aguayente was the only industry in Guam up to the time of American occupation. It has been prohibited by an official order on account of its evil effects upon our men."

TAPPING THE PALM.

The method of collecting the sap in Madras is described by Cleghorn⁴⁷ as follows:

"When the spathe is a month old, the flower-bud is considered sufficiently juicy to yield a fair return to the (*Sánár*) toddy-drawer. * * * The spathe when ready for tapping is 2 feet long and 3 inches thick. It is tightly bound with strips of young leaves to prevent expansion, and the point is cut off transversely to the extent of one inch. He gently hammers the cut end of the spathe to crush the flowers thereby exposed and to determine the sap to the wounded part, that the juice may flow freely. The stump is then bound up with a broad strip of fibre. This process is repeated morning and evening for a number of days, a thin layer being shaved off on each occasion, and the spathe at the same time trained to bend downwards. The time required for this initiatory process varies from five to fifteen days in different places. The time when the spathe is ready to yield toddy is correctly ascertained by the chattering of birds, the crowding of insects, the dropping of juice and other signs unmistakable to the *Sánár*. * * * When the juice begins to flow the hammering is discontinued. A single spathe will continue to yield toddy for about a month, during which time the *Sánár* mounts the tree twice a day and empties the juice * * *"

Molisch⁴⁸ states that, while working in Java, he could not obtain any sugar sap from the coconut palm when he followed the directions of Semler⁴⁹ and cut the young flower stalk completely off. He followed the native method and bound the young inflorescence as shown in text figure 3.



FIG. 3.—Young inflorescence of coconut palm. (a) Base of the flower stalk; (b) cut end from which the sugar sap flows; (c) female flower. One-seventh natural size.

In the morning and evening a small slice about 0.5 centimeter long was cut from the end *b* and after four or five days the sap began to flow.

⁴⁷ Watt, George, *A Dictionary of the Economic Products of India*, Calcutta (1889), 2, 449.

⁴⁸ *Sitzungsber. Akad. d. Wiss math-nat. Klasse Wien* (1898), 107, 1256.

⁴⁹ *Die tropische Agrikultur*, Wismar (1886), 1, 596.

The practice in the Philippines is about as described by Cleghorn and by Molisch except that the inflorescences are never deprived of the spathe. The flowing sap is caught in a receptacle, usually a joint of bamboo, and is gathered at morning and at night. At the time of collection, a thin slice is cut from the spathe in order to keep the wound fresh and open, or otherwise it would heal and the flow of the sap cease.

The process of collecting the tuba from the coconut, because of the height of the trees, entails more labor than with the nipa and other palms, the inflorescences of which are closer to the ground. To facilitate the labor of gathering tuba from the coconut palms, the usual practice is to attach bamboo poles from tree top to tree top, forming bridges upon which the collector can pass without descending to the ground, until his receptacle is full. (See Plates X and XI.) Since the coconut blossoms throughout the year, the tuba season is continuous, and when one stalk is exhausted, another is tapped to take its place. The number of stalks on any one tree tapped at one time seldom, if ever, exceeds three and is usually less.

The natives in some parts of the Islands plant a special coconut for the production of sap. This variety produces a small, hard nut, has a shorter trunk and is supposed to give a greater flow of sap of a better quality. The life of the tree is supposed to be shortened when it is used for continuous sap production, although Safford⁵⁰ states:

"The extraction of tuba does not injure the trees in any way, but the cutting of leaves causes injuries from which it takes years to recover."

THE YIELD OF SAP.

The flow of sap from each inflorescence varies during the age of the flower stalk and is stated by the natives to be less during the heat of the day than at night, an assertion which is shown by my investigations to have some foundation. There are variations due to the age and condition of the tree, the character of the soil and the climatic conditions. The daily yield is variously estimated.

Cleghorn⁵¹ states that forty trees yield about 12 Madras measures ($1\frac{1}{2}$ to 2 gallons), 5.68 to 7.57 liters daily, 7 measures in the morning and 5 in the evening, equivalent to about 200 cubic centimeters per day for each tree.

Schortt⁵² says that the yield will vary according to the locality of the tree and the age of the spathe; 3 or 4 quarts (2.84 to 3.79 liters) is the average quantity obtained in 24 hours for a fortnight or three weeks.

In Ratnágiri, India, the yield is said to vary from 35 to 64 imperial gallons

⁵⁰ *Cont. U. S. Nat. Herb.* (1906), 9, 243.

⁵¹ Watt, George, *A Dictionary of Economic Products of India*, Calcutta (1889), 2, 449.

⁵² Watt, *Ibid.*, 450.

from each tree, in Kolaba 4.2 pints (2.2 liters) a day, or 10.5 imperial gallons (47.7 liters) a month. This is equivalent to a rate of 1.56 liters per day.

Lyon⁵³ states that more than a liter a day is sometimes drawn from one tree, and 5 hectoliters are considered a fair annual average from a good, bearing palm.

Molisch,⁵⁴ in Java, has made the most accurate measurements of the sap flow from single inflorescences during their period of production. From January 9 to 23, 1898, fourteen days, one inflorescence gave 8 liters of sugar sap, equivalent to 0.57 liter per day, and the flow would probably have continued longer. A second inflorescence gave, from January 10 to 19, nine days, 4.87 liters, equivalent to 0.54 liter per day. A third from January 10 to 24, fourteen days, gave 4.526 liters, an average of 0.324 liter daily, when the flow ceased. In one of these cases cited, when the flow was at its height, considerably more than 1 liter a day issued from a single stalk.

My own observations in the Philippines agree fairly well with the data of Molisch, although no accurate measurements of the flow during the life of a single inflorescence have been attempted. In some cases, especially in the thirty-three days' test of 100 trees described later, I have obtained considerably larger yields. Twelve different trees, the flow in each measured from one inflorescence during the night, practically twelve hours, gave respectively 665, 635, 575, 470, 360, 360, 440, 440, 240, 670, 310, and 500, an average of 472 cubic centimeters. In each case at least one other inflorescence on each tree was also flowing sap. No account was taken of these, since the investigation at that time was not planned to measure the sap flow. Native tuba gatherers and distillers variously estimate the production of each tree from 1 to 2 liters daily throughout the year. A tree will grow about 10 fruit stalks annually and each one will run sap for about two months. Trees in good condition, growing in good soil, produce about 400 liters of sap annually and are in their prime when about 40 years old. Young trees often produce less than 300 liters. It is to be noted that this estimate may often be reduced materially by improper handling of the trees, by typhoons, and other local causes.

An investigation of seven distilleries in the Province of Tayabas revealed the fact that the average daily production of 5,785 trees from April, 1909, to March, 1910, inclusive, was 0.65 liter per tree. (Usually two inflorescences were flowing sap.) The data for each of the seven distilleries are tabulated as follows:

⁵³ *Bull. P. I. Bur. Agr.* (1905), No. 8, 12.

⁵⁴ *Loc. cit.*, 1258.

TABLE XVII.—*The yield of sap. Statistics for seven distilleries in Tayabas Province for the year, April, 1909, to April, 1910.*

Distillery No.	Trees tapped.	Yearly production.	Average monthly production of tuba.	Average daily production from each tree.
		<i>Liters.</i>	<i>Liters.</i>	<i>Liters.</i>
1.....	697	162,355	13,529	0.65
2.....	1,052	261,193	32,649	1.03
3.....	1,086	280,899	23,408	0.72
4.....	400	93,096	7,758	0.65
5.....	700	89,698	7,475	0.36
6.....	1,000	143,204	12,350	0.41
7.....	850	215,751	17,979	0.71
Average.....				0.65

^a Data for 8 months only available.

These data led to the belief that the daily and annual production obtained by the distillers from the trees was much below that which could be secured by proper management. A test of 100 trees over a period of one month was planned in order to demonstrate the results which could be achieved by the employment and efficient supervision of sufficient and competent labor to gather the tuba and keep the trees in good condition to produce the greatest flow of sap. A distiller in the Province of Tayabas coöperated with us, and 100 average trees in a grove in which his distillery was located, were properly marked so that they could be distinguished readily, and sufficiently experienced tuba gatherers were detailed to collect the tuba and perform the daily routine of cutting the stems. The supervision of these laborers and the details of the test were conducted by Mr. Thomas Hoey, agent of the Bureau of Internal Revenue in the district, to whom the credit for the successful prosecution of the investigation, and my thanks for assistance to me while carrying on the work in the Province of Tayabas, are due.

The tuba was gathered twice during the day, in the morning and evening, and the flowing flower stems were cut twice daily at the time the tuba was collected.⁵⁵

⁵⁵ Mr. Hoey states: "Two men did the work, one in the morning and one in the afternoon. The walks are so arranged that the *mangitero* starts in at the first tree of the walk and travels from tree to tree on bamboo bridges, taking the tuba until he comes to the last tree of the walk. This work was under the close supervision of the Government gauger stationed at the distillery and the tuba was measured by him.

Slices were cut from the flower stem twice a day, at the time of gathering the tuba in the morning and evening. It has been found that, while an increased daily yield may be obtained by cutting the flower stem oftener, the stem will be entirely cut away before the flow is at an end. A test by me showed that a tree produced 1.5 liters for two slicings and 2.0 liters for three slicings in twenty-four hours."

The data are tabulated as follows:

TABLE XVIII.—*Yield of sap obtained from 100 coconut trees for a period of thirty-three days, from April 13 to May 15, 1910.*

Date.	Night yield.			Day yield.			Total liters.	Rain.
	Finish- ed work.	Hours run.	Liters of tuba.	Finish- ed work.	Hours run.	Liters of tuba.		
	<i>a. m.</i>			<i>p. m.</i>				
April 13-----	7. 23		133	5. 40	10. 17	46	179	
April 14-----	7. 41	14. 01	67	6. 05	10. 24	51	118	
April 15-----	8. 15	14. 10	96	6. 09	9. 54	50	146	
April 16-----	8. 17	14. 08	98	6. 48	10. 31	51. 5	149. 5	
April 17-----	8. 00	13. 12	70	7. 00	11. 00	43	113	
April 18-----	8. 03	13. 03	90	6. 30	10. 27	61	151	
April 19-----	7. 55	13. 25	77	6. 00	10. 05	42	119	3 to 3.15 p. m.
April 20-----	8. 50	14. 50	97	6. 01	10. 11	52	149	
April 21-----	8. 00	13. 59	68	6. 05	10. 05	59	127	3.05 to 3.10 p. m.
April 22-----	8. 53	14. 48	110	6. 02	9. 09	46	156	
April 23-----	8. 05	14. 03	81	6. 03	10. 25	45	126	2.35 to 10 a. m.
April 24-----	8. 21		105	7. 03		100	205	8 a. m. 24th to
April 25-----	8. 38		162	6. 43		93	255	8.22 p. m. 25th.
April 26-----	8. 50	14. 07	72	6. 45	9. 55	53	125	
April 27-----	8. 13	13. 28	67	6. 49	10. 36	51. 5	118. 5	
April 28-----	8. 03	13. 14	62	6. 31	10. 28	52	114	
April 29-----	7. 53	13. 22	58	6. 50	10. 57	50	103	
April 30-----	7. 30	12. 30	70	6. 53	11. 20	75	145	2.10 to 5.15 p. m.
May 1-----	7. 42	12. 49	73	7. 00	11. 18	50	123	
May 2-----	8. 02	13. 02	75	7. 21	11. 19	49	124	
May 3-----	7. 11	13. 50	65	6. 39	11. 28	47. 5	112. 5	
May 4-----	7. 22	12. 43	95	7. 03	11. 41	48	143	
May 5-----	8. 49	13. 46	88. 5	6. 50	11. 01	60	148. 5	8.20 to 8.50 a. m.
May 6-----	8. 04	13. 14	76	6. 29	10. 25	59. 5	135. 5	
May 7-----	8. 12	13. 43	103. 5	7. 01	10. 49	60	163. 5	
May 8-----	9. 02	14. 01	85	6. 51	9. 49	45	130	
May 9-----	8. 07	13. 18	79. 5	6. 53	10. 45	60	139. 5	
May 10-----	7. 50	12. 57	98	7. 02	11. 12	49. 5	147. 5	
May 11-----	8. 01	12. 59	75. 5	6. 39	10. 38	47	122. 5	
May 12-----	8. 20	13. 41	92. 5	6. 12	9. 52	75	167. 5	
May 13-----	8. 11	13. 59	81	7. 02	10. 51	72	153	
May 14-----	8. 15	13. 13	87. 5	7. 10	10. 55	79. 5	167	
May 15-----	8. 32	13. 22	90	8. 23	11. 51	69. 5	159. 5	
Total, 33 days---			2, 843			1, 892. 5	4, 735. 5	

If the two rainy days, April 24 and 25, which are above the average for tuba production, are omitted, the flow for the thirty-one days is found to be as follows:

TABLE XIX.—Yield of sap obtained from 100 coconut trees during the day and during the night for a period of thirty-one days. Two collections per day, morning and evening. Data compiled from Table XVIII.

	Night flow.		Day flow.		Total.
	Liters.	Time in hours and minutes.	Liters.	Time in hours and minutes.	
31 days, yield -----	2,443	<i>h. m.</i> 406 57	1,699.5	<i>h. m.</i> 329 38	4,142.5
Average per tree -----	0.83	13 28	0.55	10 18	1.38
Average rate of flow of each tree for 12 hours -----	0.74	12 00	0.64	12 00	1.38

These results show that when the trees are properly handled by a sufficient number of men to gather the tuba and to cut the stems in order to keep the wounds flowing freely, the average daily production of each tree is approximately 1.4 liters and that the flow during the day is nearly as great as that obtained during the night when calculated in twelve-hour periods, namely, 0.64 as against 0.74 liter.⁵⁶

When it is recalled that the figures in this estimate of 1.38 liters production daily are obtained from a test of 100 average trees on thirty-one rainless days, and that the actual result under native methods is 0.65 throughout the year and including the rainy season, it is seen that intelligent management will increase the production per tree by over 112 per cent.

THE COMPOSITION OF THE SAP.

With F. AGCAOILI.

I have some reason to believe that the composition of the sap varies, and is effected by all of the conditions which influence the sap flow, namely, the age of the inflorescence and the age, condition, and local surroundings of the tree.

Samples of sap were collected from eight different trees in the Province of Laguna during the month of January and four different trees in the Province of Tayabas in the month of April, 1910. It is necessary to take the samples during the dry season to avoid contamination by water. The analyses are given in Table XX.

⁵⁶ Copeland (The Philippine Agriculturist and Forester, (1911), 1, 50), from the investigation of two spathes obtained a much greater flow at night than during the day. He states: "Further, a greater flow during the night is to be expected a priori, as a direct result of exactly the same factors which cause more rapid growth during the night." The maximum flow was 0.304 liter during the night, an amount much below the average.

TABLE XX.—Analyses of the sap of 12 coconut trees.

Sample No.	Age of tree, approximate, years.	Number of flower stalks flowing sap at the time the sample was collected.	Flow from one flower stalk during the night.	Density 15°.	Total solids.	Acidity as acetic.	Alcohol.	Ash.	Polarization at 30°.	Invert reading at 31°.	Sucrose by Clerget's formula, grams per 100 grams.	Sucrose in 100 cubic centimeters.	Invert sugar.	Preservative employed.
1	40	2	665	1.0675	17.75	0.03	None.	0.38	15.02	-3.84	14.67	15.66	0.87	1 cc. formalin.
2	40	2	635	1.0686	18.08	—	None.	0.40	14.28	-3.70	13.94	14.99	1.78	Do.
3	40	2	575	1.0670	17.25	0.03	None.	0.34	14.92	-3.80	14.57	15.55	0.39	1 g. HgCl ₂ .
4	40	2	470	1.0683	17.97	—	None.	0.36	15.23	-3.90	14.88	15.89	—	Do.
5	20-25	2	360	1.0670	17.95	—	Trace.	0.39	10.75	-1.34	12.14	12.95	7.13	1 cc. formalin.
6	20-25	2	360	1.0670	17.95	—	None.	0.32	14.12	-3.86	13.52	14.42	1.53	Do.
7	20-25	2	440	1.0720	19.13	0.08	None.	0.39	15.31	-3.88	14.94	16.02	0.71	1 g. HgCl ₂ .
8	20-25	2	440	1.0680	18.32	—	None.	0.47	14.99	-3.96	15.53	16.49	0.71	Do.
9	25	2	*240	1.0455	12.57	0.92	Trace.	0.44	-3.0	-3.3	0.23	0.24	10.70	Chloroform.
10	40	3	670	1.0710	17.69	0.06	None.	0.45	6.0	-0.2	4.81	5.11	13.43	Do.
11	50	3	310	1.0800	20.19	0.03	None.	0.35	9.0	-1.1	7.8	8.42	10.70	Do.
12	12	3	500	1.0780	19.58	0.05	None.	0.43	8.2	-2.2	8.0	8.60	10.70	Do.

* The sap flow was, in this case, much reduced for the reason that a thin slice was not cut from the inflorescence before the collecting bottle was put in place. The results are expressed as grams per 100 cubic centimeters except when otherwise noted.

The first eight samples were collected from 6 o'clock in the afternoon to 6 o'clock in the morning, January 24 to 25, 1910, from trees near Nagcarlan in the Province of Laguna, and the last four, from 6.30 o'clock in the afternoon, April 3, 1910, to 6.10 o'clock in the morning, April 4, 1910, from palms at Cotta in the Province of Tayabas.

Since the sap begins to change almost immediately on dropping from the stalk, the preservatives were put into the collecting bottles before they were put in place upon the trees. The samples preserved with formalin remained perfectly clear and almost colorless for a number of days, while those containing mercuric chloride were milky with a suspended precipitate when the collecting bottles were removed. This white precipitate of nitrogenous material gradually settled, leaving a clear, supernatant liquid.

Fresh sap, in which no chemical change has taken place, from an average tree in its prime, will probably have about the following composition:

Results stated as grams in 100 cubic centimeters.

Density	1.0700
Total solids	17.5
Acidity	Trace.
Ash	0.40
Sucrose	16.5
Invert sugar	Trace.
Undetermined nitrogenous compounds, etc.	0.60

I believe invert sugar practically to be absent in fresh juice, although the most perfectly preserved samples contained 0.39 per cent.

Samples numbered 9, 10, 11, and 12 were in transit seven days before the analyses were begun. Chloroform therefore will not prevent the action of the invertase, unless the bottles are completely full and air is excluded.

In addition to the substances above enumerated the samples were found to contain nitrogenous compounds, an invertase, yeast cells, and molds. The white precipitate in one was separated by filtration and without any attempt at purification was found to contain 2.93 per cent nitrogen or 18.3 per cent protein. The invertase performs its work so rapidly that it causes the sucrose to disappear within a very short time after the sap exudes from the stem, unless precautions are taken to inhibit its action.

A sample of tuba collected by a native in the usual manner and representing a composite from a number of trees was preserved with a large excess of formalin. The collections were made at 7 a. m. from the bamboo joints which had been filled by the night's flow and the sample was preserved three hours later.

The analysis gave the following figures expressed as grams per 100 cubic centimeters:

Density at $\frac{15^{\circ}}{15^{\circ}}$	1.0100
Total solids	3.72
Acidity as acetic	0.68
Alcohol	6.00
Ash	0.41
Sugars:	
Polarization at 30°	—0.65
Invert reading	—1.02
Sucrose by Clerget per 100 grams	0.29
Invert sugar	1.95

The great rapidity with which the alcoholic and other processes of fermentation progress is to a large extent due to the employment by the natives of old, dirty bamboo joints as receiving vessels, no attempt being made at cleanly methods.

It seems remarkable that more complete analyses of the sap as it exudes from the inflorescence are not on record. The following are the only ones available.

The Tropical Agriculturist states:

"From time immemorial, the natives of Ceylon have known how to produce crystallized sugar from the inspissated juice of the coconut tree spathe."⁵⁷

Calmette⁵⁸ in recording an investigation of coco and rice beer as made in Java, Tonkin, and Saigon writes that the sap of the coconut palm contains from 9 to 13 per cent of sugar and that the fruit is a good substitute for malt.

Doctor Lyon⁵⁹ has observed that when collected in pots which have previously been used, the fermentation commences before the pots are removed from the trees and that the toddy appears to attain its maximum alcoholic strength within twenty-four hours after removal from the tree. He also noted that the rapidity of fermentation and the yield of alcohol vary in different samples and gives the maximum alcoholic strength as 11.9 per cent proof spirits, equivalent to 5.86 per cent alcohol by weight. This is equivalent to an original sucrose content of between 12 and 13 per cent.

THE UTILIZATION OF THE SAP.

Alcoholic beverages.—The fresh, sweet sap, called *toddy* in India and various parts of Malaysia, and *tuba* (Tagalog) in the Philippines, is used as a beverage to some extent, but the major portion is not drunk until after fermentation. Since this process begins at once, unless some

⁵⁷ *Trop. Agric.* (1883), 568.

⁵⁸ *Chem. Centralbl.* (1894), 2, 394. *Centralbl. f. Agrikulturchemie* (Viederman) (1895), 24, 357. *Vierteljahrschr. d. Chem. d. Nahrungs-u. Genussmittel* (1894), 9, 98.

⁵⁹ Watt, George, *A Dictionary of the Economic Products of India*, Calcutta (1889), 2, 455.

precautions are taken to prevent it, the above names seem to apply to the sap at all of its stages prior to distillation.

In India and parts of Malaya the beverage resulting from the distillation is called *arrak* and, in the Philippines, *vino de coco* (Spanish) and *alak* (Tagalog). Some vinegar is produced from the sap of the coconut palm in the Philippines, but I believe but little or no sugar is made from it.

Watt⁶⁰ states that the juice ferments rapidly and becomes intoxicating. "This is the *tari* or *toddy* (or in the case of the coconut more specifically known as the *nira*), a beverage very extensively consumed in India. Fermentation is said to be prevented by the addition of a little lime to the fluid. The earthen vessels into which it drains are generally powdered with lime when the fluid is to be drunk in its fresh unfermented state, or is intended to be boiled down to sugar or *jaggery*. * * * When fermented the juice may be distilled into spirits or made into vinegar. One hundred gallons of *tari* yields on an average twenty-five of *arak* by distillation."

Since the sap will produce an average of 6 per cent alcohol, the *arak* is thus estimated to be about 24 per cent in alcoholic strength. In another place Watt⁶¹ states the liquor to be 80 proof, or about 40 per cent alcohol.

"Of Ratnágiri, it is said, there are ordinarily three kinds of palm spirit, known respectively as *rási*, *phul* or *dharti*, and *phéni*; *rási* being the weakest and *phéni* the strongest. In some places a still stronger spirit called *duvási* is manufactured. * * * The spirits are distilled in private stills, licensed to be kept at certain Bhandáris' houses under fixed conditions as required, in proportion to the number of trees licensed to be tapped in the vicinity. One still is usually allowed for every 100 trees, and the still-pot is limited to a capacity of 20 gallons." ⁶²

Production.—The production of beverages in the Philippines distilled from the fermented sap of the coconut has increased since the enactment of the present Internal Revenue Law and the business is becoming concentrated in four provinces. At various times eleven provinces have been identified with the industry. At the present time, it is on a substantial basis and the output is increasing.

These facts are brought out in Table III in the introduction, pages 102 and 103.

During the calendar year 1909 there were twenty-eight distilleries, all of the pot type, engaged in the industry. They handled 5,756,764 liters of coconut sap, from which they produced 705,376 liters of distilled beverages of an average proof of 74, or 37 per cent alcohol. These distilled beverages were all sold locally, usually within a small radius of the distilleries, under the name of *vino de coco*. The composition of these coco whiskies will be considered in Part 2 of this article which will be published at an early date.

The available data from a number of distilleries operating in the four provinces where the industry of distilling coco sap is carried on are given in the following table:

⁶⁰ *Loc. cit.*, 451.

⁶¹ *Ibid.*, 457.

⁶² *Ibid.*, 451.

TABLE XXI.—*The cost of production and the selling price of the various grades of coco distillates together with the available data for the production from a few distilleries and provinces during the calendar year 1909.*

[The prices in this table are expressed in Philippine currency. One peso is equivalent to \$0.50 United States currency.]

Province.	Distillery No.	Tuba distilled during 1909.	Total for province.	Liters of tuba required to produce 1 proof liter of alcohol.	Per cent of alcohol obtained from tuba.	Proof of spirits sold.			Cost of producing 1 proof liter exclusive of tax. ^a	Selling price of the various grades per liter.				Average price per—	
						High.	Low.	Average.		75 proof.	87 proof.	94 proof.	100 proof.	Proof liter.	Gauge liter.
Tayabas	1	162,355	1,273,396	7.40	6.76	96	85	90.5	0.19	0.333		0.50		0.50	0.416
Do	2	261,193		8.23	6.07	92	72	82	0.20	0.366	0.40	0.50		0.52	0.422
Do	3	280,899		8.43	5.93	91	82	86.5		0.333	0.433	0.466	0.60	0.52	0.458
Do	4	93,096		7.52	6.65	95	86	90.5		0.333	0.433	0.466		0.49	0.411
Do	5	89,698		8.18	6.11	94.5	None.		0.21			0.50		0.54	0.50
Do	6	148,204		7.85	6.37	96	None.		0.22			0.50		0.54	0.50
Do	7	215,751		7.89	6.33	94	None.					0.516		0.55	0.515
Laguna ^b	All.	2,108,286	2,108,286	7.84	6.38	103	66	78						0.425	0.33
Albay	1	683,719	1,145,119	8.35	5.99	59.5	47.5	57						0.466	0.25
Do	2	511,400		10.3	4.85	91	43	58.5						0.41	0.225
Ambo Camarines	1	337,820	1,257,163	7.6	6.58	58	46	55						0.39	0.19
Do	2	478,760		8.65	5.73	70	57	60						0.407	0.245
Do	3	336,400		7.84	6.38	77	57	60						0.40	0.245
Do	4	554,183		8.88	5.63	58	52	55						0.39	0.22

^a The cost of production given in the table are the distillers' own figures, but I have no reason to doubt their approximate accuracy.

^b During the fiscal year 1910, 10,109 trees were employed in Laguna Province for the production of tuba. Data for other provinces are not available.

For a period of thirty days during the months of February and March, 1910, accurate measurements were made of the amounts of tuba and the yields of alcohol obtained therefrom at seven distilleries in the Province of Tayabas. The tuba was daily collected from the trees, but the stills were run only when a sufficient quantity had collected at the distillery to warrant lighting the fires.

TABLE XXII.—*Record of thirty days' run of seven distilleries in the Province of Tayabas.*

Distillery No.	Number of trees in use.	Number of days of production during the period.	Sap handled during this period, in liters.	Liters of sap handled in the stills on working days.	Daily production from each tree.	Number of proof liters of alcohol produced.		Average proof of the alcohol.		Percentage yield of alcohol from the sap.
						High grade.	Low grade.	High grade.	Low grade.	
126	697	15	12,117	807	0.60	438	968	96	87	5.4
325	1,050	17	36,480	2,146	1.16	1,249	3,306	92	72	6.2
329	1,086	20	21,060	1,053	0.64	1,872	769	94	83	6.3
372	400	7	5,062	723	0.42	460	193	95	86	6.1
582	700	6	7,427	1,288	0.35	973	None.	96	-----	6.6
533	1,000	14	18,106	1,293	0.60	2,172	None.	97	-----	6.0
604	850	13	24,240	1,865	0.95	2,817	-----	94	-----	5.8

A study of these data shows that the average amount of alcohol which the sap of the coconut palm yields is 6.1 per cent by volume, equivalent to an original sucrose content of 9.5 per cent.⁶³ The original saps average 3 to 6 per cent more sucrose than this figure. The great loss of alcohol which occurs, partly during fermentation and partly during distillation, is to be expected because of the crude methods employed.

The fact is also brought out that natives of some provinces drink a beverage much higher in alcohol than do those in others. Investigation seems to show that it is the native taste which governs the character of the product and not the idiosyncrasies of the distiller.

All of the distilleries are small and the present tendency is toward an increase in numbers in the provinces where the industry is most flourishing. These conditions are brought about by the difficulty in carrying the sap to a distillery located at any considerable distance from the source of production. Almost all of the transportation is now done in petroleum tins holding about twenty liters each. Two of these are suspended from a stick over the shoulder of the porter.

When the system of roads and bridges, now under construction in the provinces, becomes more extended the transportation of sap to greater distances will be made easy, and, no doubt, many of the smaller and

⁶³ Grams of alcohol times 1.96.

more inefficient plants will give way to centrally located distilleries which will draw upon a large area for the raw material.

COSTS.

The average price paid for the distilled beverages at the distillery is 0.475 peso per liter (0.352 peso per proof liter) to which must be added the internal-revenue tax of 0.25 peso per proof liter. The cost of production was found to vary from 0.19 to 0.22 peso per proof liter. These figures, it is to be noted, were furnished us by four different distillers and they show a profit to them of about 0.15 peso per proof liter. I have no doubt that this is greater at some distilleries. With scientific management it could be greatly increased at every distillery engaged in the industry.

A survey of the factors which govern the cost of the raw material indicates at once that, while as a source of industrial alcohol this cost is excessive, the profit to the distiller of beverages is large. In many localities the standard price of tuba is 0.01 peso per liter. If the alcohol production is taken at 6.5 per cent by volume, the cost of the raw material to produce 1 proof liter of alcohol is 0.077 peso and for 1 liter of alcohol of 180 proof, 0.138 peso. In some localities the price of tuba delivered at the distillery is 0.012 peso.

A typical case representing the cost of the raw material to one distiller is as follows:

He rents 1,800 trees for 1 peso each per year and obtains about 219.6 liters of tuba per tree. He pays 0.15 peso for the gathering of each 19.5⁶⁴ liters, which makes the cost of each liter 0.0124 peso. The records of his distillery show that he obtains an average of 6.07 per cent (by volume) of alcohol from the tuba. The raw material thus costs him 0.0976 peso to make one proof liter of alcohol and 0.176 peso for one liter of alcohol of 180 proof.

As a source of alcohol much cheaper native substances are to be found.

The ordinary pot or whisky still, usually without a doubler, is the standard apparatus employed. (See Plate XIII.) The cost in pesos of such a plant, typical of provincial practice, is as follows:

Stills and condensers in Manila	₱1,300
Freight and mounting	500
Building	250
Four tanks	750
Total	1,800

Before operation is commenced, an internal-revenue tax of 200 pesos must be paid. This latter item is repeated annually.

⁶⁴The standard of 19.5 liters which is so often used is the capacity of the 5-gallon Standard Oil Company's tin, which is so much used in the provinces that it has a standard value.

THE SAP OF THE COCONUT PALM AS A SOURCE OF SUGAR.

No case of the use of the sap of the coconut palm for the production of raw or crude sugar by the natives has been found in the Philippines. If any sugar is made in this way the amounts must be exceedingly small. In other countries fair quantities of sugar are produced from this source.

The Tropical Agriculturist⁶⁵ states that about thirty years ago (about 1853) the question of utilizing coconut palms for sugar arose in Ceylon.

"The result of our inquiries was that although the juice, when collected, was rich in saccharine matter, yet the cost of collection would render the enterprise unprofitable. What pays the native on a small scale will not pay Europeans when the matter is entered into on commercial principles."

Jayewardene⁶⁶ writes that sugar manufactured by the natives is found in almost every peasant's hut in Ceylon.

"The process of manufacture followed by them is as follows: Meera, or sweet toddy, which is made from ordinary toddy by putting a few pieces of *hal potu*, the bark of the *Vateria indicans* [= *V. acuminata* Hayne] cut small into the pot that receives it from the flower to prevent its alcoholic fermentation and thus retain its sugar unchanged, is boiled down to a thick sirup called *peni*. The *peni*, when cool, is poured into clean earthenware vessels and placed on the *duma* (which answers to the hob in an English household) where a slow evaporation and a deposition of crystals takes place."

Schortt⁶⁷ in describing the process as carried on in India states:

"The sap is poured into large pots over an oven, beneath which a strong wood fire is kept burning, the dead fronds and other refuse of the plants being used as fuel. The sap soon assumes a dark-brown semi-viscid mass, well known as *jaggery* or *gúr*, which whilst warm is poured into earthen pots or pans for preservation. Ten to twelve seers of the sap yield one of *jaggery*; * * *. The *jaggery* is placed in baskets and allowed to drain; the watery portion or molasses dropping into a pan placed below. This is repeated, so that the *jaggery* or sugar becomes comparatively white and free from molasses. * * *. Thus cocoa-nut sugar is chiefly met with in the form of *jaggery*. It is well known, however, that it is capable of being refined, according to European principles, and a certain amount of cocoa-nut sugar is regularly prepared."

Crude sugar is made in Guam⁶⁸ by boiling down the fresh tuba in kettles over an open fire.

"Coconut sugar is not made so extensively in Guam at the present time as formerly, before copra was in such great demand; but there are natives who still make it rather than buy imported sugar from the stores, and many families use the sirup 'almibar de tuba dulce' in their daily economy."

VINEGAR.

Watt⁶⁹ states that the toddy produces a very good vinegar on undergoing acetous fermentation. "The vinegars prepared from the juices of the various

⁶⁵ *Trop. Agr.* (1883), 568.

⁶⁶ *Ibid.*, 573.

⁶⁷ Watt, George, *A Dictionary of the Economic Products of India*, Calcutta (1889), 2, 452.

⁶⁸ Safford, *Loc. cit.*

⁶⁹ *Loc. cit.*, 455.

palms that yield such juice do not appear to have been carefully examined. The natives of India attribute peculiar properties to each."

Lyon⁷⁰ states that: "The vinegar as produced is of good strength and color, of the highest keeping qualities and of unrivaled flavor. Its excellence is so pronounced that upon its merits it would readily find sale in the world's markets; and although the local demand for the tuba now exceeds the production, its conversion into vinegar will probably prove the more profitable industry in the future."

In the Philippines, some vinegar is produced wherever the coconut tree is tapped for its sap. Five samples have been obtained and analyzed. One was bought by me in the open market at Nagcarlan, Laguna Province, and was pronounced by a resident to be good vinegar. Four samples were forwarded by Mr. M. E. McFarland from Maripipi, Leyte. Two of these were made with the addition of tan-bark. (*Ceriops tagal* C. B. Robinson and *Rhizophora mucronata* Lamarck.) He states that the natives pound the tan-bark to a powder and put small quantities into the bamboo tubes used for collecting the sap. The proportion is about a tablespoonful to the liter. The samples prepared with tan-bark are brown, while the others are almost colorless. The reasons for the use of the tan-bark are not understood. I believe that it improves the taste. This is partly due to the astringency of the tannin and partly to the inhibition of a putrid fermentation which sets in very shortly after the sap has flowed from the tree. Much of the nitrogenous substances of the sap are precipitated by the tannin.

TABLE XXIII.—Analyses of samples of coconut-sap vinegar.

By F. AGCAOILI.

Component.	Samples from Nagcarlan.	Samples from Leyte.				
		Sap taken from tree in April and analyses made in July, 1910.			Sap taken from tree in March and analyses made in July, 1910. Prepared with tan-bark.	
		No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
Density.....	1.0100	1.0132	1.0132	1.0400	1.0400	
Total solids.....	2.06	3.57	3.56	1.62	1.45	
Ash.....	0.45	0.55	0.56	0.53	0.57	
Alcohol.....	7.37	4.50	4.50	5.25	5.25	
Acetic acid.....	1.51	3.41	3.31	3.00	3.00	
Polarization.....	+2.20	0.00	0.00	0.00	0.00	
Tannin.....	0.00	0.00	0.00	0.025	0.031	
Reducing sugars.....		0.67	0.68	0.63	0.83	

⁷⁰ Loc. cit.

It is to be noted that in all of the samples there is a large percentage of alcohol which has not been changed to acetic acid.

The analyses show the results of the crude methods employed by the natives throughout the Archipelago. It would appear that there is a potential possibility of producing good vinegar from this material.

THE BURI PALM.

Corypha elata Roxb.

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Table XXVIII.

DISTRIBUTION AND HABITAT.

The buri palm is one of a small genus consisting of about half a dozen very closely related species, which includes the talipot palm of Ceylon and the fan palm of India. It is distributed from Bengal and Ceylon to the Sunda Islands. The products are so much alike as to be known by the same name, regardless of the species from which they are derived.

Watt⁷¹ states that since Roxburgh views *C. umbraculifera* as the intermediate form between *C. taliera* and *C. elata*, for industrial purposes they may be regarded as but forms of one plant and it is impossible to correlate the various properties assigned to them.

Corypha umbraculifera L. has been considered to be the buri of the Philippines, but Doctor Beccari has determined the Philippine material sent to him as representing two or more species of the genus, and he considers it doubtful if the true *C. umbraculifera* L. occurs in the Archipelago.

⁷¹ A Dictionary of the Economic Products of India, Calcutta (1889), 2, 577.

The buri is found throughout the Philippines at low altitudes and is reported as being very abundant in the Provinces of Mindoro, Pampanga, Tayabas, Sorsogon, Camarines, and Pangasinan. The Island of Burias derived its name from the buri because of the great number of the palms of that kind found growing on it.

A map showing the distribution is reproduced on page 170.⁷² It has been corrected through the division superintendents of the various provinces and is probably as accurate as can be compiled without actually sending surveying parties into the field.

Merritt and Whitford of the Bureau of Forestry describe the growth in Mindoro as follows:⁷³

"Behind the mangrove and nipa swamp is a belt not flooded at any time by the tide, yet containing too much water for the growth of forest trees. Here is usually an almost pure stand of the buri palm. Toward its higher limits it is mixed with shrubs and forest trees and merges into the forest types. Reproduction is very plentiful, and large numbers of young plants are to be found. The buri palm is not necessarily confined to the area bordering on the nipa, but may form dense growth along the streams, especially if these run through or border on the grass areas."

In order to estimate the commercial value of the buri palm, for purposes which will be brought out later, an accurate estimate of the stands on the Island of Mindoro, where the results seemed to be most promising, was made at the request of the Bureau of Science by the Director of Education. Mr. C. W. Franks, division superintendent of schools for the Province of Mindoro, carried on the work through the teaching force of his division. He insisted on a very careful survey and the estimates are no doubt approximately correct. They are as follows:

"In the Mamburao, Maasin, Pagbahan, and Santa Cruz regions there are 7 principal stands and several smaller ones, in all about 34 hectares and containing about 15,000 palms, of which about 4,500 are matured. The average is 130 matured palms to the hectare and 300 in the Santa Cruz district, where there are about 12 hectares.

"In the Sablayan district there are 6 large stands totaling 57 hectares and containing about 39,500 palms, of which 21,560 are matured. Of these the Bulanglot district contains 20 hectares averaging 534 matured palms or a total of 10,680 matured palms.

⁷² This map, prior to its correction, was first published in Bulletin 33, Bureau of Education, entitled "Philippine Hats," by Hugo H. Miller.

⁷³ *Bull. P. I. Bur. For.* (1906), No. 6, 25.

"In the San José district there is a total of about 107 hectares covered with buri palms averaging about 1,500 young palms and 500 medium and old palms per hectare or a total of about 214,000, of which 53,500 are matured. Nearly all are on the land of the Mindoro Development Company.

"In Bulalacao and Mansalay there is a total of about 50 hectares covered by buri palms, of which there are about 1,000 young and about 400 medium and old palms per hectare, or a total of 70,000 palms of which 20,000 are mature.

"The Pinamalayan-Cawayan district has 9 stands containing a total of about 3,803 hectares and 927,974 palms, of which 73,134 are mature. The mature palms are not dense, 60 to the hectare being the greatest number and the average being about 20.

"The Polo district has a total of about 167 hectares in 2 stands containing about 67,600 palms, of which 3,100 are matured.

"The Naujan district has a total of about 510 hectares in 4 stands covered by about 379,750 palms, of which 35,750 are mature.

"The Calapan district contains a total of about 278 hectares in 9 stands where there are about 204,817 palms, of which 19,012 are mature. The largest stand is near Gutod and contains about 14,550 matured palms in 150 hectares or about 97 to the hectare.

"In these various regions the palms do not grow in one stand but in scattered groups."

It is thus found that about 5,006 hectares of land on this island are covered by 1,918,141 buri palms, of which number 226,094, or about 12 per cent, are mature trees.

DESCRIPTION.

The buri is a stout, erect palm with a crown of large, fan-shaped leaves. It is of slow growth, but attains a very great size; it flowers and fruits but once, the fruit terminating the stem; and after the ripening of the fruit, the tree dies. There are no statistics available, but it seems to be a common belief that the life of a buri palm is not less than twenty-five to thirty years. During the latter part of its existence, great quantities of starch are stored in its trunk. At the time of maturity an enormous, pyramidal, terminal inflorescence is produced and the leaves fall from the tree.

USES.

Although the buri, unlike the coconut palm, furnishes no products of commercial value worth mentioning outside of the Philippines, with the possible exception of hats, the many uses to which its parts are put by the natives of this Archipelago give it a great importance. In respect to this the buri ranks second to the coconut in the Islands.⁷⁴

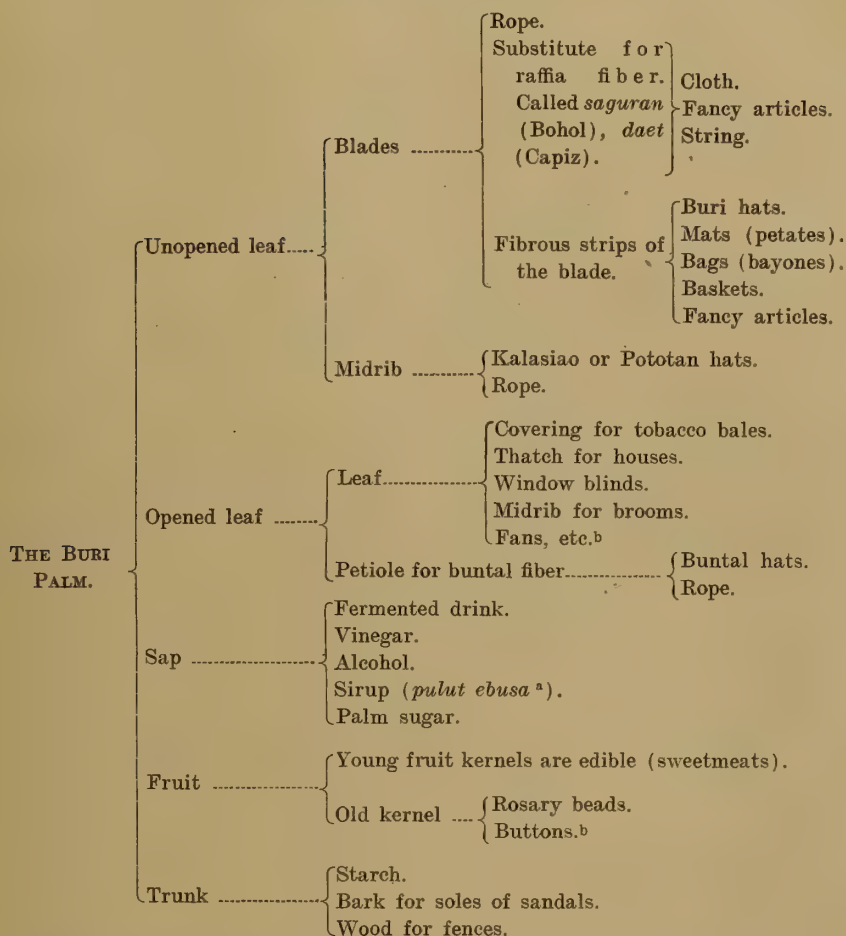
⁷⁴Concerning the possibility of using certain parts of the buri for paper making, see *Philippine Fibers and Fibrous Substances: Their Suitability for Paper Making (Part II)*. G. F. Richmond. *This Journal* (1906), 1, 1083.



Map No. 3.

These uses are classified as follows:⁷⁵

Uses for the buri palm.



^a The Pampangan dialect for buri sirup, *pulut* meaning sirup, and *ebus*, the name of the palm.

^b Not a use in the Philippines.

In the Philippines, many of these uses date from the earliest history of the Islands. In 1579 Gabriel de Ribera ⁷⁶ states that, their expedition being short of food, they cut down large quantities of [buri] palm trees on the Island of Mindanao and were four days engaged in preparing starch. Again he states:⁷⁷

"The chief food of the river of Mindanao is *landan*, which is made from certain palm trees very abundant in that land, called buri. After soaking this

⁷⁵ I am indebted to Hugo H. Miller, of the School of Commerce, for the diagram and other information.

⁷⁶ Blair and Robertson, *The Philippine Islands*, Cleveland (1903), 4, 276.

⁷⁷ *Ibid.*, 284.

substance they make from it a sort of flour which is their food. For this reason they do not sow much rice, although they have rice fields."

The only uses which give any promise of commercial possibilities, outside of the manufacture of hats ⁷⁸ from the fiber, are the production of sugar and alcohol from the sap, and starch from the trunk. The production of sugar, alcohol, and starch are considered in this article. At present, all of these uses are only of minor local importance and give little promise of future development into industries of great magnitude.

THE SAP.

METHODS FOR PRODUCING SAP FLOW.

The sap is obtained in two different ways which are outlined below. However, in a number of places the natives seem only to be familiar with the first method and can not be made to believe that the second way is feasible, so firmly rooted is custom. A possible third method is also described.

First method.—The inflorescence is cut across near its base and for protection against the sun and rain a small roof made of leaves is fastened in place. Large quantities of sap exude from the wound. It is collected by running into a small earthen jar.

Second method.—In Tayabas and some other provinces, the natives do not wait for the flowering period to tap the trees for the tuba, as they state that the sap will flow from some trees at any time. The trees are stripped of their leaves, the top is bound with bamboo hoops eight or ten centimeters apart for a distance of about one meter down and is then cut off so that the heart of the trees is exposed. This top surface is cut and channeled, producing a clean tissue which is continually exposed to the air, but protected from the sun by a covering of leaf thatch. In three or four days, sometimes at once, the sap begins to flow steadily and rapidly. Buri palms in process of producing sap are illustrated in Plates XV and XVI.

Unlike the nipa and coconut plams, which bear tapping year after year for long periods, the buri completes its life history with its one flowering season and, when either of the first two methods is pursued, it can be tapped but a single season for sap.

Third method.—It is possible that sap may be obtained by the method of tapping sometimes employed in India on the Palmyra palm, *Borassus flabellifer* Linn. Near the apex the outer layers are removed from a triangular space the dimensions of which are about twenty centimeters on each side. The sap flows from this place when the surface is kept fresh by frequent cutting. When one place is sufficiently cut away a fresh area can be opened. This method has not been tried to my knowl-

⁷⁸ The manufacture of hats is an industry of much local importance in some places. The town of Lucban, Tayabas Province, produces about 5,000 per week. See Robinson, *This Journal*, Sec. C (1911), 6, 115.

edge, but it has been suggested to me by Dr. E. B. Copeland, of the College of Agriculture, that if it were practicable the duration of sap flow from this palm might be extended over a period of years. Moreover, since it is probable that the time of flowering is determined, to some extent at least, by the accumulation of starch, the sap flow will so reduce the stores of starch that the flowering may be greatly postponed and the life of the tree prolonged.

The natives of Tayabas have a superstition that the tree will burst if a woman touches or interferes with it in any way while the sap is flowing. I offered the wife of the man who cut the tree under my supervision 10 pesos if she would ascend the bamboo ladder reaching to the top of the tree so that I could see the phenomenon. She refused the money, which to her was a large sum, and her husband explained to me that the tree might not burst to-day if she went up the ladder, but it would to-morrow or the next day.

COMPOSITION OF THE SAP.

Samples of sap were obtained by me from time to time from five different buri palms, and analyzed. The first three trees were growing within 300 meters of each other under the influence of equal climatic and soil conditions in Marilao, Province of Bulacan. They were tapped by the natives according to the first method, when the tree was in flower, and according to the owners all the trees were about 30 years old. The sap flowed during the following periods:

Tree No.	Flow commenced.	Flow ceased.	Duration of sap flow.
1	February 1, 1910 -----	May 15.-----	3.5 months.
2	December 1, 1909 -----	April 11, 1910 -----	4.5 months.
3	March 27, 1910 -----	-----	No record.

These three trees were not tapped under my supervision, but were found in a flowing condition. The natives who owned and tapped them gave me the dates for the beginning of the flow and therefore they are to be taken only as approximate. Sap was collected at intervals for analysis from trees numbered 1 and 2, until the flow ceased.

The fourth tree was about 12 years old and was tapped, according to the second method, under my direct observation. The top was cut on April 5. Three days later, on April 8, the sap flow commenced and continued until May 30, at which time the tree died. The duration of the sap flow was therefore not quite two months.

The fifth tree, at Bokawe, Bulacan, was more fully investigated than any of the others and forms the subject of a separate section. Accurate studies of the daily yield of sap, the total yield, the manufacture of sugar, and some other questions of interest were included in this investigation.

The analytic and other data concerning the first four trees are tabulated as follows:

TABLE XXIV.—*Analyses of sap of four buri palm trees and estimates of the rate of sap flow.*

Tree numbered 1 at Marilao, Bulacan. ^a															
Sample No.	Date of collection.	Time of collection.	Amount collected, cc.	Rate per day in liters.	Density.	Total solids in 100 cc.	Ash.	Acidity as acetic.	Sugars.				Remarks.		
									Polarization at 30°.	Invert reading at 30°.	Sucrose by Clerget's formula.	Sucrose in 100 cc.		Reducing sugars.	
1	1910. Mar. 12	8 a. m.	850	---	1.0644	14.20	---	0.09	+	13.5	3.1	12.90	13.7	1.53	Sample not preserved until after collection. 1 gram mercuric chloride.
2	Mar. 12	8 a. m. to 9 a. m.	850	20.40	1.0600	15.53	---	0.07	12.0	3.0	11.62	12.3	2.06	Preserved with 1 cc. formalin.	
3	Mar. 12	9 a. m. to 10 a. m.	850	20.40	1.0612	14.60	0.39	0.10	13.9	3.3	13.33	14.1	0.26	Preserved with 1 g. mercuric chloride.	
4	Mar. 28	8.55 to 10.04 a. m.	500	10.43	1.0624	16.96	0.39	0.09	15.2	4.3	15.10	16.0	0.63	Preserved with chloroform.	
5	Apr. 11	9.23 to 9.54 a. m.	500	23.23	1.0580	14.59	0.43	0.15	15.0	2.2	13.33	14.1	0.89	Do.	
6	Apr. 19	7.15 to 7.40 a. m.	350	20.17	1.0555	13.57	0.34	0.06	12.7	2.7	12.00	12.7	0.21	Preserved with formalin and toluene.	
Tree numbered 2 at Marilao, Bulacan. ^b															
1	Mar. 12	9 a. m.	850	---	1.0435	9.90	0.39	0.05	7.23	2.06	7.20	7.5	0.67	Preserved with 1 cc. formalin.	
2	Mar. 16	7.30 to 8.09 a. m.	1,150	42.46	1.0358	8.98	0.41	0.04	7.12	1.38	6.6	6.8	0.13	Preserved with chloroform.	
3	Mar. 16	8.10 to 8.53 a. m.	1,150	38.53	1.0360	9.03	0.43	0.04	7.17	1.56	6.73	7.0	0.10	Do.	
4	Mar. 28	8.12 to 8.33 a. m.	520	35.67	1.0360	9.88	0.31	0.07	-1.4	7.15	4.46	4.6	4.86	Preserved with chloroform but not analyzed until two weeks after collection.	
5	Apr. 11	7.33 to 8.45 a. m.	520	34.05	1.0475	11.95	0.38	0.18	10.0	3.3	10.31	10.8	1.34	Preserved with chloroform.	

^a Tree died May 15.^b Tree died between April 11 and 19.

Tree numbered 3 at Marilao, Bulacan.														
1	May 18	11.24 to 11.33 a. m.	240	38.40	1.0500	12.79	0.34	0.03	12.0	2.2	11.08	11.6	1.03	Preserved with toluene.
Tree numbered 4 at the Barrio of Lumbang near Lucena, Tayabas. ^c														
1	Apr. 9	Before 10.30 a. m.	1,240	-----	1.0410	9.29	0.35	0.08	7.0	1.0	6.20	6.5	2.14	Collected by native and later preserved with chloroform.
2	Apr. 9	11.54 a. m. to 12.54 p. m.	440	10.56	1.0420	9.26	0.35	0.02	6.0	2.2	6.43	6.7	1.98	Preserved with chloroform.
3	Apr. 22	5 to 6 a. m.	810	19.44	1.0568	13.94	0.39	0.03	1.5	2.5	3.12	3.3	7.64	Do.
4	May 4	10 to 10.35 a. m.	870	35.88	1.0428	10.22	0.32	0.06	4.0	1.3	4.11	4.3	5.35	Do.
5	May 4	1.20 to 1.50 p. m.	890	42.72	1.0400	9.24	0.59	0.07	1.0	1.2	1.71	1.8	6.70	Do.
6	May 15	6.50 to 7.22 a. m.	735	33.07	1.0387	9.61	0.87	0.04	-1.8	-2.0	0.6	0.7	8.00	Do.
7	May 15	7.29 to 8.05 a. m.	720	28.81	1.0370	8.44	0.60	0.02	1.6	-1.7	2.6	2.7	5.00	Do.

^c Tree died May 30. Samples collected on May 22 and 29 lost in transit.

An invertase proferment or zymogen, also present in the sap, has previously been described in the chapter on the nipa palm. The large amount of reducing sugars found in some of the samples is due to the length of time which elapsed during their transportation from the provinces to the laboratory in Manila and the lack of complete precautions to inhibit the action of the invertase. Since no measurements of the flow of sap of these four trees were made for an entire twenty-four hour period, the figures for the daily flow are only approximate. It has been observed that this rate is greatest just after the surface has been newly cut. An increase of as much as 50 per cent in the rate can be produced temporarily by fresh cutting and since the majority of the samples was collected immediately after cutting, it is probable that the estimated rates of flow are too great. Nevertheless, it is evident that three of the trees had an astonishingly large flow of sap, probably in the neighborhood of 30 liters for twenty-four hours. The amount of sugar in the total sap flow can be estimated about as follows:

Sugar in total sap flow of the buri palm.

Tree No.	Estimated daily flow.	Approximate sugar content.	Daily sugar yield.	Duration of sap flow.	Total sugar yield.
	Liters.	Per cent.	Kilos.	Days.	Kilos.
1	20	14	2.8	100	280
2	30	8	2.4	135	324
4	40	9	3.6	50	180

There is no reason for believing that these estimates of the yields of sugar from mature trees are exaggerated.

The sap richest in sugar obtained from the four buri trees as it flowed from the tree had approximately the following composition:

Density $\frac{15^{\circ}}{15^{\circ}}$	1.0700
Total solids	17.0 per cent.
Ash	0.43 per cent.
Acidity (as acetic)	0.06 per cent.
Sucrose	16.0 per cent.
Reducing sugars	Small amounts or traces.
Undetermined solids	0.51 per cent.

FERMENTATION OF THE SAP.

With W. B. GONDER and F. AGCAOILI.

As it flows from the tree and for a short time thereafter, the sap is colorless, odorless and neutral or slightly alkaline to litmus paper and phenolphthalein. If heated to boiling it becomes alkaline to both these indicators and remains colorless about two hours longer than sap not heated.

A viscous, followed by a putrid fermentation, develops in the sap on standing, when no precautions are taken to inhibit their action. Both

fermentations have about the same properties as those which Spencer⁷⁹ describes as occurring in sugar-cane juices.

Viscous fermentation.—"The solution becomes thick, slimy, and ropy; and starchy matters and sugar are transformed into gummy substances. This fermentation takes place spontaneously. Small quantities of carbonic acid and hydrogen are liberated."

Putrid fermentation.—"The solution becomes turbid and viscous; ammonia is set free, and a sediment deposits. The fetid odor is repulsive."

The only changes in the sap which were investigated are the inversion of the sucrose, and the alcoholic and acetic fermentations as they progress spontaneously. The only control of the fermentations attempted was for the purpose of inhibiting all changes to preserve samples for analyses and for the manufacture of sugar.

Inversion of the sucrose.—The sucrose begins to invert in about five hours and the process is complete in about thirty. Three samples collected on three different days gave the following results:

TABLE XXV.—*Spontaneous inversion of the sucrose of the sap.*

Time interval.	Direct polarization.			Per cent of inversion, approximate.
	Aug. 19, 1910.	Aug. 23.	Nov. 3.	
<i>Hours.</i>				
1.0			+9.6	0.0
1.5		+10.6		0.0
2.	+11.5			0.0
2.5		+10.6		0.0
3.0			+9.6	0.0
3.5		+10.6		0.0
4.	+11.5			0.0
4.5		+10.6		0.0
5.	+11.5		+9.6	0.0
5.5		+10.2		10.5
6.5		+9.4		17.5
7.0			+9.4	2.1
7.5		+9.0		21.0
8.0			+9.2	4.2
8.5		+8.2		28.1
9.0			+6.8	29.0
9.5		+7.0		38.6
10.0		+7.0		38.6
11.0			+6.4	33.3
12.0			+5.4	44.3
13.0			+3.4	64.9
18.0	+4.6			61.4
20.0	+3.6			69.5
22.0	+2.4			80.0
24.0			+1.2	87.6
26.0			+0.8	91.7
28.0			+0.3	96.9
30.0	-0.3		-0.1	100.0
30.5		-0.8		100.0

⁷⁹ A Hand Book for Cane Sugar Manufacturers, New York (1906), 228.

The minus reading gradually returns to zero as the sugars disappear by fermentation. When sap is collected in alcohol, no fermentation of any kind results and an albuminous precipitate gradually settles out. Since this precipitate was supposed to contain the enzyme causing the inversion, a portion was filtered from a 50 per cent alcohol solution of sap, washed and placed in a pure sugar solution under toluene.

Initial rotation	+9.7
After 24 hours	+9.7
After 20 days	+9.0

This precipitate is inactive, while that which forms spontaneously in the sap is active.

Alcohol fermentation.—A comparatively small yield of alcohol results from the spontaneous fermentation of the sap of the buri palm.

Fresh sap containing 10.5 per cent sucrose was allowed to stand until the latter had decreased to 1 per cent, and then the alcohol was determined at intervals.

Date.	Time in hours.	Alcohol by volume.
November 9, 1910.....	24	2.0
November 10, 1910.....	48	2.0
November 14, 1910.....	72	1.65
November 15, 1910.....	168	.65

Other samples of sap yielded about 3 per cent of alcohol.

Acetic acid fermentation.—Fresh sap collected at 11.30 in the morning of August 19, 1910, being neutral at the start, showed the following acid fermentation:

Time interval.	Acidity.	
	cc. of tenth normal sodium hydroxide required to neutralize 100 cc.	Calculated as acetic.
0 hour.....	Neutral or slightly alkaline.	
2 hours.....	Neutral or slightly acid.	
4 hours.....	4	0.024
5 hours.....	5	.030
24 hours.....	48	.288
26 hours.....	54	.324
22 days.....	315	1.890

A second sample collected at 6 o'clock in the morning of August 23, 1910, showed the following acid fermentation:

Time interval.	Acidity.	
	cc. of tenth normal sodium hydroxide required to neutralize 100 cc.	Calculated as acetic.
1.5 hours-----	0.5	0.003
2.5 hours-----	1.5	.009
3.5 hours-----	2.0	.012
4.5 hours-----	3.0	.018
5.5 hours-----	4.5	.027
6.5 hours-----	7.0	.042
7.5 hours-----	9.0	.054
8.5 hours-----	11.0	.066
9.5 hours-----	13.0	.078
10.0 hours-----	14.0	.084
30.5 hours-----	42.0	.252

A third sample collected November 6, 1910:

Time interval.	Acidity.	
	cc. of tenth normal sodium hydroxide required to neutralize 100 cc.	Calculated as acetic.
3 days-----	96.0	0.575
5 days-----	177.0	1.062

The rates of inversion and alcoholic and acid fermentations are plotted in text figure number 4, page 180.

It is evident that the greater portion of the reducing sugars is changed by the viscous, putrid, and other fermentations rather than by the alcoholic, in the spontaneously fermenting sap.

Inhibition of the fermentations.—Toluene, chloroform, formaldehyde, alcohol, and lime were employed in various samples of the sap from all the trees investigated. Toluene and chloroform give satisfactory results when it is desired to preserve the samples only for a few hours. They do not prevent the action of the invertase. Formaldehyde has only a temporary effect unless the amounts employed are excessively large.

A satisfactory method of preserving the sap for some purposes consisted in collecting it in a bottle containing a known amount of alcohol, as it dropped from the tree. The alcohol inhibits all changes in the sap.

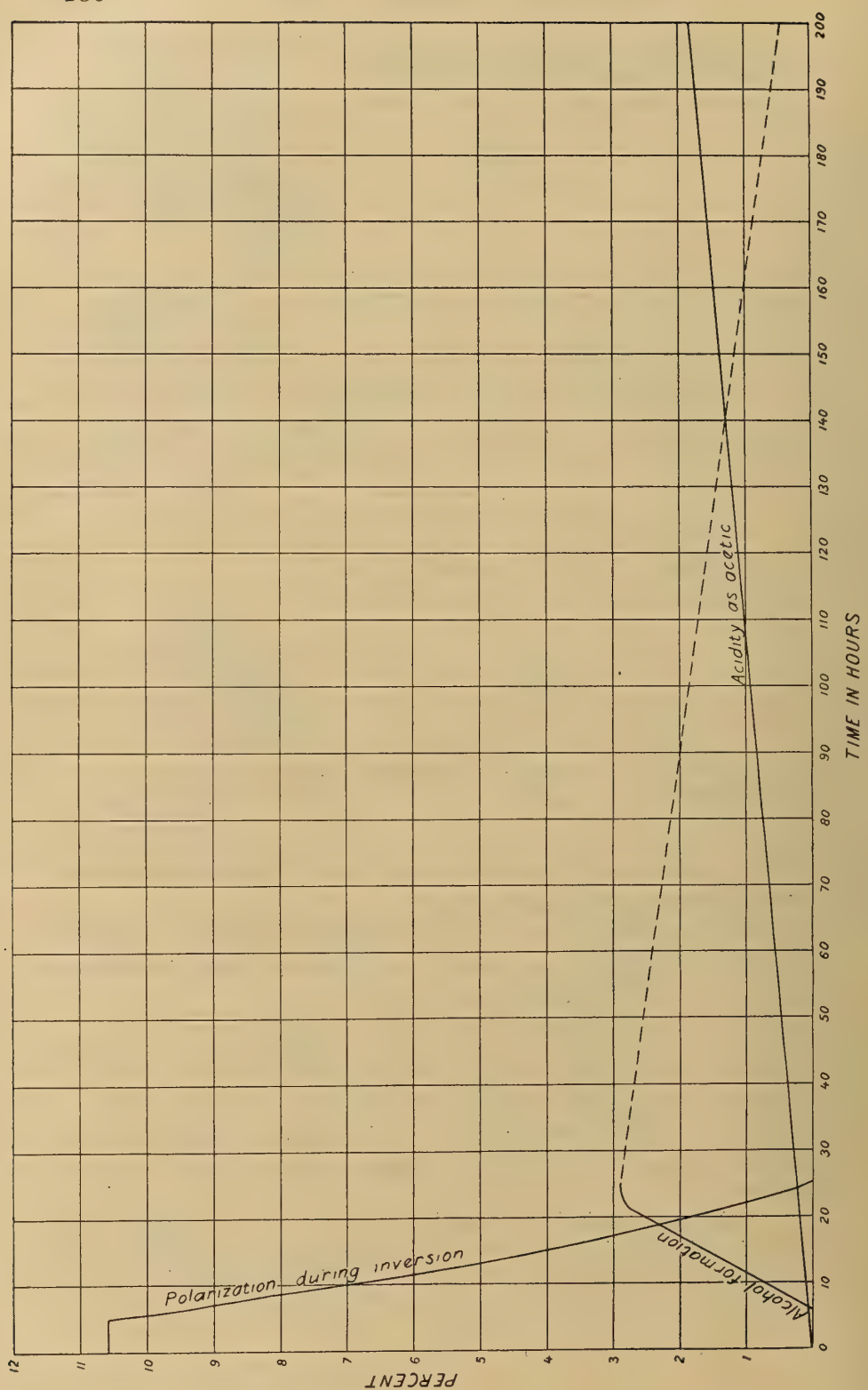


FIG. 4.

A sample from tree number 5 was collected in this way, and the analysis showed the following composition:

Analysis of sap collected in alcohol.

	Alcoholic sample.	Calculated to original sap.
Density.....	1.0305	
Solids.....	12.86	14.3
Ash.....	0.33	0.35
Polarization:		
Direct.....	-11.6	
Invert.....	- 3.0	
Sucrose.....	11.3	12.6
Reducing sugars.....	0.32	0.35
Acidity.....	0.036	0.04
Alcohol.....	16.1	0.00
Purity.....		88.1
Undetermined.....		0.96

Alcohol slowly precipitates a white, flocculent, nitrogenous compound leaving a clear supernatant liquid. When containing from 10 to 16 per cent alcohol by volume the sap forms an agreeable beverage, too sweet perhaps for some palates.

Alcohol was also found to be very serviceable in the filtration of the solutions for polarization after the addition of the clarifying agent. Many of the samples were so viscous that they could not satisfactorily be filtered without this aid. When a volume of alcohol equal to that of the clarifying reagent employed (lead subacetate) is added, the precipitate settles quickly and the solution passes rapidly through the filter.

Slaked lime is the most practical preservative for the sap when it is to be used in sugar making. The inversion of the sucrose and other changes are inhibited by its use. For other purposes it does not appear to have any value. The use of slaked lime is more fully treated in the section on sugar making.

INVESTIGATIONS CARRIED ON WITH TREE NUMBER FIVE.

With W. B. GONDER.

Description of the tree.—A group of about twenty buri palms ranging in age from twelve to thirty-five years is located two miles east of Bokawe, Bulacan, in the Barrio of Turo. One of these was selected for the following investigations:

The palm was, by native report, more than forty-five years old, but this is scarcely credible. An estimated age of thirty or thirty-five years is more in keeping with the best estimates of the age limits. The circumference at the base was 2.115 meters, and the height was 11.11 meters. The leaves were many, of good size and color, and everything indicated that the subject selected for experimentation was an average specimen approaching maturity.

Tapping for sap.—The services of an experienced native were employed for this work. A bamboo ladder was first constructed and placed at the palm. Ascend-

ing this, the branches of the palm were all removed with a bolo, the conical top securely bound around its circumference with bamboo rope, after which the top of the cone was removed by slicing it horizontally, a lip being cut in the side through which the sap could drain to a bamboo spout, which emptied into a receptacle. A bamboo covering was made and placed over all in such a manner as to protect the top and sap from the sun, rain, and wind.

The tapping or removal of the top of the cone occurred at 9.20 a. m. August 1, 1910, and almost immediately the sap began to flow.

Flow of sap.—The daily flow can be regulated to a considerable degree by the extent to which the cut surface is kept fresh. This is explained by stating that a very thin slice is removed from the cut surface at intervals, to prevent the pores becoming clogged and stopping the flow. Native superstition demands great care and experience in removing this slice from the cut surface to prevent the complete cessation of the flow. These precautions seem to have little foundation, as the assistant in charge of the tree undertook its care, after observation of the method of slicing for a time, with no bad results. Natives state that there is a greater flow of sap by night than by day. Observations upon this point do not entirely bear out the belief. When the slices are removed twice during the twenty-four hours, at 6 o'clock in the morning and at 6 o'clock in the afternoon, the sap flow fluctuates, sometimes being greater in the night than in the day, sometimes vice versa and sometimes approximately equal. For example:

Rate of sap flow from a buri palm in 12-hour periods; two cuttings each 24 hours.

Date.	Flow.	
	Day.	Night.
	cc.	cc.
October 19, 6 a. m. to 6 p. m. -----	15,920	
October 19, 6 p. m. to October 20, 6 a. m. -----		15,410
October 20, 6 a. m. to 6 p. m. -----	17,410	
October 20, 6 p. m. to October 21, 6 a. m. -----		14,290
October 6, 6 a. m. to 6 p. m. -----	16,050	
October 6, 6 p. m. to October 7, 6 a. m. -----		17,020
October 7, 6 a. m. to 6 p. m. -----	16,250	
October 7, 6 p. m. to October 8, 6 a. m. -----		17,110
October 28, 6 a. m. to 6 p. m. -----	15,960	
October 28, 6 p. m. to October 29, 6 a. m. -----		15,910
November 5, 6 a. m. to 6 p. m. -----	12,500	
November 5, 6 p. m. to November 6, 6 a. m. -----		12,410

The differences were found in a measure to be due to the variation in thickness of the slice removed. A daily decreasing rate of flow can often be changed to an increasing one by augmenting the thickness of the

cuttings. An apparently dying flow can thus be revived. On two different occasions this was demonstrated.

First.		Second.	
Day.	Yield.	Day.	Yield.
	cc.		cc.
Fifth	5,400	Fifteenth	1,425
Sixth	5,130	Sixteenth	915
Seventh	4,720	Then thicker slices were removed.	
Then thicker slices were removed.		Seventeenth	1,555
Eighth	6,250		

The rate of sap flow is influenced to a marked degree by the number of daily cuttings. For six days three cuttings were made during each period of twenty-four hours, at 6 o'clock in the morning, 12 noon, and 6 in the afternoon. The day flow was thus made greater than the night flow, as is shown by the following figures:

Rate of sap flow from a buri palm in 12-hour periods; three cuttings each 24 hours.

Date.	Flow.	
	Day.	Night.
	cc.	cc.
August 2, 6 a. m. to 6 p. m.	3,030	
August 2, 6 p. m. to August 3, 6 a. m.		2,800
August 3, 6 a. m. to 6 p. m.	3,050	
August 3, 6 p. m. to August 4, 6 a. m.		2,370
August 4, 6 a. m. to 6 p. m.	3,110	
August 4, 6 p. m. to August 5, 6 a. m.		2,400
August 5, 6 a. m. to 6 p. m.	2,960	
August 5, 6 p. m. to August 6, 6 a. m.		2,440
August 6, 6 a. m. to 6 p. m.	2,990	
August 6, 6 p. m. to August 7, 6 a. m.		2,140
August 7, 6 a. m. to 6 p. m.	2,680	
August 7, 6 p. m. to August 8, 6 a. m.		2,040

It is possible that there is a tendency toward a greater sap flow at night than during the day, since the transpiration will be less at night and consequently a greater hydrostatic pressure will exist in the trunk.

The following is a record of the daily flow of sap from the palm, all measurements being from 6 in the morning to 6 in the evening; beginning at 9.21 on the morning of August 1, 1910:

TABLE XXVI.—Daily flow of sap and the per cent of solids as measured by the Brix spindle.

Day.	Yield in cubic centimeters.	Percent of Brix corrected to 30°.	Day.	Yield in cubic centimeters.	Percent of Brix corrected to 30°.	Day.	Yield in cubic centimeters.	Percent of Brix corrected to 30°.
1	3,815	-----	45	9,870	14.1	89	31,870	11.0
2	5,830	11.5	46	11,970	13.8	90	39,540	10.6
3	5,420	-----	47	14,480	13.9	91	25,730	11.1
4	5,510	-----	48	19,630	13.5	92	24,510	11.1
5	5,400	10.8	49	21,770	13.3	93	23,420	11.1
6	5,130	-----	50	22,520	13.3	94	23,490	11.3
7	4,720	-----	51	24,180	13.0	95	26,160	10.8
8	6,250	-----	52	26,870	12.9	96	27,110	-----
9	6,420	-----	53	30,760	12.4	97	24,910	10.4
10	3,960	11.8	54	27,690	12.4	98	25,440	10.8
11	3,340	11.9	55	28,200	12.9	99	27,150	-----
12	3,170	12.0	56	32,450	12.2	100	36,240	10.2
13	2,260	12.2	57	33,860	12.0	101	42,360	10.0
14	1,440	11.9	58	33,700	11.7	102	44,780	9.8
15	1,425	11.8	59	23,230	11.9	103	45,640	9.7
16	915	12.0	60	29,160	12.5	104	44,470	9.7
17	1,555	12.0	61	20,840	12.0	105	45,230	9.6
18	1,675	12.4	62	17,710	12.4	106	44,890	9.4
19	2,420	12.5	63	19,270	12.4	107	42,340	8.6
20	2,770	11.9	64	29,730	11.7	108	41,970	9.0
21	3,690	12.0	65	29,640	11.7	109	41,100	9.1
22	4,380	12.3	66	23,420	11.9	110	39,080	-----
23	4,170	12.6	67	33,070	11.3	111	39,230	-----
24	4,010	12.7	68	33,360	11.6	112	39,090	-----
25	4,180	12.8	69	36,030	10.8	113	39,100	-----
26	4,290	12.8	70	27,580	11.2	114	37,950	-----
27	5,240	13.1	71	23,820	11.7	115	36,500	-----
28	6,680	13.3	72	31,960	10.8	116	36,240	-----
29	6,990	13.3	73	21,560	11.4	117	38,610	-----
30	6,670	13.6	74	20,870	11.6	118	38,550	-----
31	6,010	13.7	75	35,490	10.6	119	36,620	-----
32	6,915	13.7	76	29,700	10.8	120	33,030	-----
33	7,180	14.0	77	24,190	11.3	121	30,910	-----
34	6,720	13.8	78	29,430	10.9	122	28,540	-----
35	7,200	13.7	79	27,680	11.0	123	24,050	8.1
36	6,460	14.4	80	31,330	10.7	124	19,650	7.8
37	5,240	14.0	81	31,700	10.3	125	17,620	8.2
38	4,880	14.2	82	24,520	10.8	126	14,590	7.6
39	4,790	14.4	83	25,910	11.3	127	12,530	7.7
40	6,630	14.1	84	25,650	11.2	128	9,980	-----
41	12,030	13.9	85	27,370	11.0	129	2,900	-----
42	10,700	13.7	86	29,990	11.2	130	940	-----
43	10,360	13.7	87	31,710	11.0	131	420	-----
44	10,160	13.9	88	32,210	10.6	132	90	-----

Tree died December 11, 1910.

Total sap flow
Average daily flow

Liters.
2,699.65
20.45

During the first sixteen days the flow was somewhat irregular, due partially to experimentation and an effort to find the most efficient thickness of slice to remove at each cutting and partially to idiosyncrasies of the tree. After this initial period the effort was made to remove slices of uniform thickness. A gradual increase in the daily flow began on the seventeenth day. It increased from approximately 1.5 liters at that time to approximately 12 liters on the forty-first day, when the palm may be said to have reached what the natives call its *malorayat* stage. This term is defined as that period when the sap is of better quality and the flow is rapid. The improvement in the quality of the sap is recognized by the increased sweetness. Previous to the arrival of the *malorayat* stage none of the sap is used as a drink or for other purposes.

The daily flow of sap and the rise and fall of the sucrose content, expressed by the Brix, may be represented by the curves shown in figure No. 5, which is compiled from the data given in Table XXVI and from analyses of the sap.

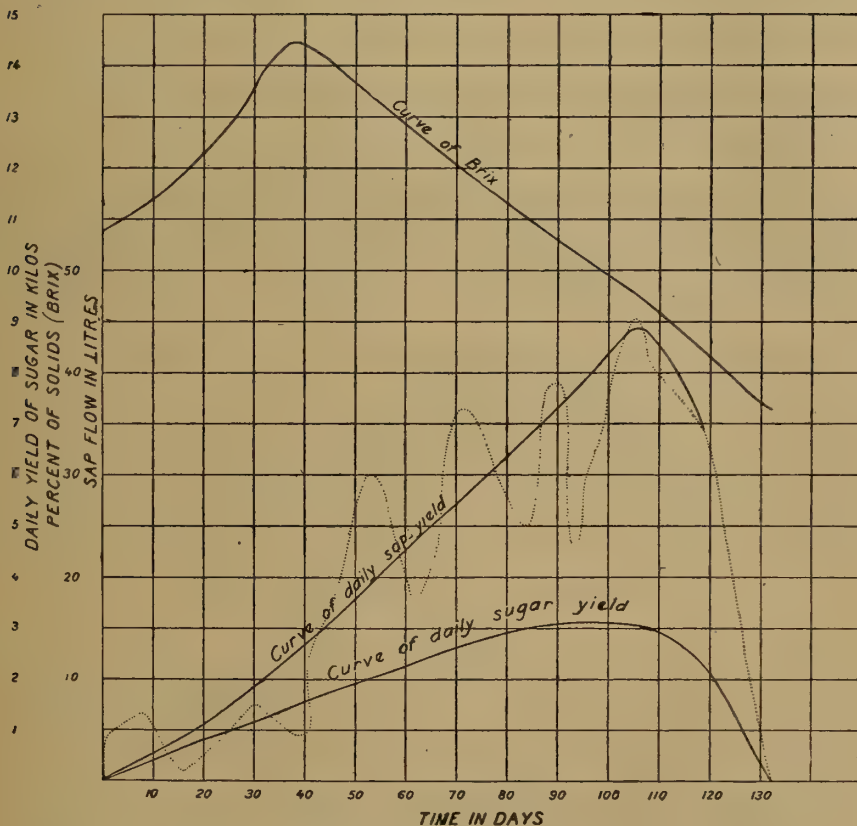


FIG. 5.—The sap flow, per cent Brix and sugar yield of the sap of the buri palm.

Analyses of the sap.—At intervals during the flow of the sap it was polarized on the spot and samples were sent to the laboratory at Manila and analyzed.

TABLE XXVII.—*Analyses of sap from tree number 5 at intervals during the sap flow.*

Date of collection of sample.	Density.	Solids.		Ash.	Direct polarization.	Reducing sugars.	Acidity.	Purity.
		Brix. ^a	By weight.					
August 4, 1910		13.2			9.1			69.0
August 5, 1910		12.7			9.2			72.5
August 10, 1910		13.1			10.2			78.1
August 17, 1910		14.1			12.0			85.3
August 18, 1910		13.0			11.0			85.0
August 19, 1910		13.5			11.8			87.2
August 23, 1910		12.5			10.6			84.1
August 25, 1910		13.3			11.2			84.1
September 2, 1910			14.3	0.35	^b 12.6	0.35	0.04	88.2
October 1, 1910	1.0525		13.92	0.49	^b 11.5	0.71	0.002	87.3
October 11, 1910		10.8			9.5			87.9
November 3, 1910		11.3			9.4			88.2

^a It is to be noted that the Brix given in this table does not coincide with that found in Table XXVI. This is due to the fact that the data given in this table are obtained from fresh samples. The Brix of the samples recorded in Table XXVI is too low because fermentation had commenced before the samples were collected, and are to be regarded as comparative rather than absolute values.

^b Sucrose by Clerget.

The purity $\left(\frac{\text{direct polarization}}{\text{sucrose by Brix}} \right)$ of the sap rose to about 84.5 per cent after the sixteenth day of flow and remained almost constant until the flow was practically completed. Since the solids were determined in the field by means of the Brix spindle, it is quite probable that the data obtained in the laboratory at Manila upon the samples shipped in are more accurate. These data place the purity at about 88 per cent.

THE MANUFACTURE OF SUGAR FROM THE SAP.

With W. B. GONDER.

The small amount of sugar made by the natives is boiled out of the fresh sap without the use of any chemicals for preservation or clarification, and before inversion has had time to progress to any considerable extent.

Theodore C. Zschokke, Forester of the Bureau of Forestry, Philippine Islands, writes as follows concerning the production of sugar:

"The sugar maker locates a grove of mature trees and builds a clay furnace near by. The furnace is built around a core which is burned out when the clay has sufficiently dried. At one side is an arched opening for feeding the fire and opposite is a grotesque face which serves as a chimney. An ordinary kettle is

fitted to the top of the furnace. Whenever the location is in danger of floods, the natives build the furnace above the high-water level, roof it over and live there.

"The sap is too sweet to be palatable as a beverage when fresh, but it makes a popular cider when fermented. Six hours are required to evaporate a kettle of sap. As the kettle is very full, the sap would boil over if this were not prevented by an open cylinder, made of strips of buri leaves, set in the kettle. Sap boiling over the top of this cylinder flows back into the kettle. When sufficiently boiled, the contents of the kettle are stirred with a rod bent to fit the curve of the kettle. The kettle is removed from the fire and the stirring continued until the sugar granulates. It is then ladled out and cooled in coconut-shell molds. Very often the sugar is poured into square or circular boxes made of buri leaves. The children also weave figures of chickens, and small bags, and fill them with sugar. This sugar sells for 2 to 3 cents (United States currency) a pound in the woods.

"The sirup is of a golden brown color and has an agreeable and distinctive flavor superior to that of the sugar. There is no market for the sirup and the sugar is sold locally, as the supply is limited.

"No data were obtainable as to the production of sap, or the proportion of sugar contained."

A sample of buri palm sugar, manufactured in Silay, Pampanga Province, was obtained in the market at Dagupan. It was packed in small boxes made of leaves. The weight of the sugar in five boxes was 83, 91, 77, 97, 82 grams, average, 86.4 grams each. These boxes retail at from 3 to 5 centavos Philippine currency in Dagupan, and at the place of manufacture, and in the country at 1 centavo each.⁸⁰ The composition of the sugar is as follows:

Analysis of buri sugar.

Moisture		8.91
Polarization	{ Direct reading	+78.4
	{ Invert reading	-22.88
Sucrose (by Clerget)		78.5
Invert sugar		8.89
Protein (N \times 5.5) 0.27		1.48
Ash		2.23
Chlorine in ash		0.33
		<hr/> 100.01

This sample was dark brown in color and was more of the consistency of candy than of crystallized sugar.

The most economical preservative employed for the manufacture of sugar from the sap is slaked lime. Formalin might also be used to advantage in addition to the lime, especially for the purpose of disinfecting the vessels employed as containers. Sugar, of excellent quality, polarizing from 94° to 98°, has been produced in this laboratory of the Bureau of Science by boiling the sap, preserved with lime, in open pans.

⁸⁰ Sample collected by Theodore C. Zschokke, Government Forester, P. I.

Six liters of sap were collected over milk of lime, the clear supernatant liquid having a Brix 12.0 at 30°; sucrose, 9.5 per cent; purity, 79.2 per cent; alkalinity, 1.36, expressed as grams of calcium oxide per 100 cubic centimeters of sap.

The alkalinity was reduced by means of carbon dioxide, the liquid filtered and concentrated to a sirup of 1,100 cubic centimeters volume. This gave a Brix of 40.0 at 30°; sucrose, 37.6 per cent; purity, 93.5 per cent, and alkalinity, 0.1316.

The theoretical yield of granulated sugar from this volume of sirup is 434 grams. On concentrating it to a massecuite, cooling, washing and drying in a hand centrifuge, 192 grams of very small crystals of sugar were obtained, polarizing 94.5 with 3.5 per cent moisture, which means that the sugar had a polarization of 98° when dry.

The molasses and washings from this first yield had a volume of 600 cubic centimeters; Brix at 30°, 38.8; sucrose, 33.4 per cent; purity, 86.1 per cent, and alkalinity, 0.14. Boiled to a second massecuite, cooled, and dried this gave a yield of 120 grams of sugar polarizing 90°.4 and 55 cubic centimeters of molasses containing 55.6 per cent sucrose.

The total yield of first and second sugars for the six liters of tuba was 312 grams, while a third sugar could have been crystallized from the second molasses had it been of sufficient volume.

The crystals of sugar were well defined and sufficiently hard. They emitted a peculiar odor, while the taste was sweet, but unlike the sweetness of sugar from the sugar cane. It was afterwards proved that the use of sulphur dioxide in the clarification eliminates the peculiar odor, but the confectionary taste remained. The natives are in the habit of boiling the buri sap to a thick sirup, cooling it and selling the mixture of molasses and mealy sugar for 3 or 4 centavos a pound as a confection. Its taste is different from that of cane sugar.

It is improbable that the buri sap can be successfully employed as an independent commercial source of sugar for the following reasons:

The preceding description of the fermentations arising in the sap shows that they can be most advantageously checked by the use of lime. An excess of lime salts in sugar solutions will prevent the crystallization of the sugar upon concentration of the solution and in order to remove them, a supply of carbon dioxide would be necessary, the chief commercial source of which would be limestone and an efficient kiln. In order to produce good, clean, dry grains of sugar, the following installations will be required: A clarifying outfit, sulphuring apparatus, filter presses, concentrating apparatus, steam generating plant, lighting plant, boiling plant, centrifuges, and transportation facilities. The cost of such a plant will necessitate an investment of practically as much money as required for a cane-sugar mill minus the crushers. An attempt to state what could be done by assembling second-hand machinery or employing the present Philippine methods of sugar production could only be regarded as a guess.

When a large stand of buri palms occurs in the proximity of a sugar mill, it seems entirely feasible that the sap can be used with the sugar

cane juice. When sulphur dioxide is employed in the clarification, the sap might be mixed advantageously with the cane juice in the clarification tanks. When sulphur dioxide is not used in working the sugarcane juice and it is boiled when neutral or slightly alkaline, the buri sap might be successfully added to the clarified cane juice and boiled into sugar after first treating the buri sap separately with carbon dioxide⁸¹ in blow-up tanks and filtering. Under such conditions no additional investment of any considerable magnitude will be required to handle the buri sap and the experiment is at least worthy of a trial when opportunity offers.

On the basis of an estimate of 100,000 buri palms growing in one locality so that the sap could be economically handled, the receipts are estimated as follows:

A yield of 3,000 liters of sap per palm would mean a total yield of 300,000,000 liters. A milling outfit corresponding to a 500-ton sugar mill can work approximately 340,000 liters of sap in 24 hours, so that a mill of this capacity could operate about 900 days. The sap would probably have an average Brix of 12.0, sucrose 10 per cent, and purity 82.0 per cent. The valuation of the yield of sugar from 300,000,000 liters of tuba would be approximately 4,600,000 pesos. Theoretically this figure is very attractive, but the conditions and costs entering into the manufacture of this sap as an independent undertaking are too uncertain and experimental to hazard any statement of the profit which might accrue. Moreover, it is to be remembered that the palm is in the best condition to be tapped for sap only once in a cycle of 25 or 30 years, unless the method of tapping for more continuous sap production can be successfully carried out.

In conclusion, the results obtained are negative and must therefore for the present place the buri palm and its products (with the possible exception of those made from the fibers) among the class of palms being of no great immediate commercial value. This verdict seems to be corroborated by natives, whose only use of the tuba is as a drink and for the manufacture of a confection after the palm is in flower.

THE STARCH.

By RAYMOND F. BACON.

It was thought advisable to determine the amount of starch in the trunk of the tree, so that, if possible, more use could be made of the immense number of buri palms in many uninhabited portions of the Islands.

A medium-sized tree on the Recoleta estate in southwestern Mindoro was cut down and portions of the trunk were collected. The trees are very difficult to fell, for while the whole interior of the palm is soft, and it is only surrounded by a thin shell of very hard wood, still, because of the many fibers on the inside, it is necessary to cut completely through the latter before the tree will fall.

⁸¹ The abundance of limestone of good quality in these Islands argues for the economic advantage of manufacturing lime for defecation purposes near the sugar mill.

The interior consists of a soft, pith-like substance with a pink tinge when freshly cut, which soon becomes of a reddish-brown color on exposure to the air.

The specific gravity of the pith as it came from the tree was 0.97; air dried, 0.72. The total water obtained by drying my specimen *in vacuo* was 59 per cent. The tree when cut down weighed 1.69 metric tons and contained 6 per cent of starch, so that about 100 kilos of starch are obtainable from an average sized tree. I was not able to wash the starch to a white color; it always had a decidedly red hue. In view of this fact and of the difficulty of separating it, of the cutting of the trees because of the many strong fibers, and because of the swampy ground over which the trunks must be transported, it is very doubtful whether the buri palm can be utilized commercially for starch or for alcohol. The starch is in large grains, which are somewhat similar in appearance to those of potato starch.

Additional notes by H. D. Gibbs and analysis by F. Agcaoili.—Since the above was written by Doctor Bacon and since his departure from the Philippine Islands I have been presented by Mr. Hugo H. Miller with a sample of buri starch and one of buri sago which were collected on a recent trip to the Island of Cebu. The starch was purchased in the market at Argao, Cebu, and the sago in the market at the capital of the province.

The starch is made by the natives in the following manner. The interior pithy portion of the trunk of the palm is cut into strips and dried. It is then pounded to separate the starch from the fiber. The fine dust is washed in cold water and the starch settled out in the usual manner and dried. The sago is made from the starch by dropping wet lumps of starch on a hot iron plate.

The same confusion of the names sago and tapioca, noted in Food Inspection Decision No. 128 of the United States Department of Agriculture, is found to some extent in the Philippines.

Analysis of the starch gave, moisture 12.05 per cent and starch 87.19 per cent. When viewed by the microscope, employing polarized light, the samples which I have examined can be distinguished readily from the starch of the sugar palm which is described later.

SOME OBSERVATIONS ON THE CHEMISTRY AND PHYSIOLOGY OF THE BURI PALM.

It has been shown that this palm stores large quantities of starch in its trunk during the long period of its growth, and it is evident that this starch is the source of the sugar which is found in the tuba. The trees which are tapped at the time of flowering, when the starch stored in the trunk is at a maximum, will therefore give the greatest yield of sugar. In this connection it is to be remembered that the synthesis of starch is at this time ended, for all of the leaves are removed from the tree when it is tapped.

Since a well-matured tree will produce, during the sap flow, from 200 to 300 kilograms of sucrose, it is quite evident that at least this quantity of starch must exist in the trunk at the time the sap flow is made to start. Doctor Bacon's estimate of 100 kilos of starch I believe to be considerably below the average. This is probably due to the fact that he did not investigate an average, mature tree.

The processes by which the starch is converted into sucrose are not clearly understood. Brown and Morris⁸² believe that sucrose is the primary carbohydrate synthesized by the chloroplasts. As such it may find its way directly into the fruit of the coconut and other palms. In the case of the date palm, where large quantities of sucrose, glucose, and fructose are stored in the fruit, Vinson⁸³ suggests that maltose is the sugar which passes into the fruit, since it will encounter a relatively low osmotic pressure, or none at all, while the other sugars must enter against a relatively high pressure.

However, in the buri, the sucrose of the tuba is formed from the storage material, starch, which is thus converted into the transportation material. Maltose might here be an intermediate product. The question of the occurrence of maltose has not been especially investigated, but from the many analyses which have been made it is evident that it can be present only in inconsiderable quantities, for the reason that the saps as they drop from freshly cut stems contain, at most, only traces of reducing sugars. Sucrose is known to be the moving carbohydrate in many plants other than the palms. As such, it is not available for the nutrition of the protoplasm but must first undergo hydrolysis. The conversion of the starch into sucrose might be accomplished by means of diastase, with maltose as an intermediate transitory stage or by means of the protoplasm itself. A diastase was found after many tests.

The early failures to detect diastase were probably due to the sampling of the trunk at points where the diastase did not exist or was not readily detected. As the sap flow goes on, the starch of the trunk disappears from the top down (and also, perhaps, more slowly from the outside toward the center) and there may be, and probably is, a moving zone where the conversion of the starch into sucrose takes place through the influence of the diastase.

St. Jentys⁸⁴ has found that the diastase in leaves is formed only in small quantities as it is required.

In his investigations of the banana and the mango, H. C. Prinsen Geerligs⁸⁵ found that the starch of the ripening fruit changes into sucrose, and while evidences of diastatic action was obtained he believes the conversion of starch into sucrose is a vital process and not a consequence of the action of some ferment.

The sap contains no diastase.

Experimental.—The slices of the stem which were daily removed to maintain the sap flow were repeatedly tested for starch and for a diastase with negative results. The sap was tested on several occasions for a diastase and none was found. The iodine test was always employed for the recognition of starch, and it is therefore possible that minute quantities were overlooked. In only a few cases was the microscopic identification resorted to. Tests for a diastase were made by maintaining at 55° a mixture of 25 cubic centimeters of a 2 per cent starch solution and from 5 to 10 grams of the substance to be tested for a period vary-

⁸² *Journ. Chem. Soc. London* (1893), 63, 673.

⁸³ *Bot. Gaz.* (1907), 43, 398.

⁸⁴ Green. *The Soluble Ferments and Fermentation*, Cambridge (1901), 21.

⁸⁵ *Arch. Java Sucker Ind.* (1908), 267; and *Intern. Sugar Journ.* (1908), 10, 372 through *Chem. Abstr.* (1908), 3, 2964 and 3414.

ing from two to forty-eight hours. The reducing sugars were then determined.

On the day that tree number 5 died, or rather ceased to flow sap, it was cut down and two sections, one about 35 centimeters from the top and the other about 40 centimeters from the ground, were immediately brought to the laboratory and analyzed.

The dimensions and the weights of the sections were:

	Top section.	Base section.
Diameter.....centimeters..	43	63
Height.....do.....	31	28
Weight.....kilograms..	47.3	86.7

From these figures it is calculated that the volumes and the densities of the sections were:

	Top section.	Base section.
Volume.....cubic meter..	0.045	0.0873
Density.....	1.051	0.9935

The average density was 1.022.

The weight of the tree is calculated from the following data to have been 2.77 metric tons:

Radius at base	0.337 meter.
Radius at top	0.215 meter.
Height	11.11 meters.
Density	1.022
Volume	2.71 cubic meters.

Borings were taken from the center and from points 2 centimeters from the outer edge of both the top and bottom sections and analyzed, with the following results:

TABLE XXVIII.—*Analyses of the wood from various parts of tree number 5 after the sap flow had ceased.*

Composition.	Top section.		Base section.	
	Inside.	Outside.	Inside.	Outside.
Moisture.....	88.30	82.40	78.80	58.78
Ash.....	1.80	2.85	1.59	1.18
Sodium chloride.....		(0.66)		
Sugars.....	Trace.	Trace.	* Trace.	2.60
Starch.....	^b None.	None.	9.00	9.78
Crude fiber.....	9.36	14.54	9.37	27.05
Total.....	99.46	99.79	98.76	99.39

* At center trace, near center 1.34 per cent.

^b Doctor Copeland found a very few starch grains by microscopic examination.

The sugars were all determined as reducing sugars, since the time required for transportation of the parts of the trunk to the laboratory was probably sufficient for hydrolysis of a considerable portion of the sucrose.

All of these samples gave negative tests for diastase. Since it was noted that the base section contained sugar, the largest amount occurring near the circumference with none, or traces in the center, borings were taken from the circumference toward the center, in such a manner as to secure a sample from the point where there was the most sugar, to one where there existed no sugar and much starch, and these samples were tested for a diastase with positive results.

The following mixtures were digested at 45° to 55° and the reducing sugars determined:

- I. Twenty-five cubic centimeters of a 2 per cent starch solution.
- II. Twenty-five cubic centimeters of a 2 per cent starch solution, plus 5 grams of the sample.
- III. Five grams sample 25 cubic centimeters water.
Ten grams of the sample were extracted with water and filtered. The filtrate was 100 cubic centimeters. The reducing sugars were determined in this solution.
- IV. Ten cubic centimeters of this solution plus 25 cubic centimeters of starch solution.

Chloroform or toluene, in some cases both, were employed to inhibit the action of living organisms.

Number II contained the largest amount of reducing sugars, numbers III and IV very small amounts, and number I practically none. Similar tests were made several times under varying conditions with the same results.

These analyses point out several noteworthy conditions of the trunk of the palm:

1. The whole trunk is saturated with water or aqueous solution which has not the characteristics of the sap, since sugars are absent except in the outer portion of the base.

2. The outer portion of the base is the only place where a solution resembling the sap was found.

3. The fibrous structure of the trunk is denser at the outside than in the inside. The data obtained from the chemical analyses merely corroborate this well-known fact.

4. The dry material of the base consists largely of starch, the amounts being 21.2 per cent for the outside portion and 42.4 per cent for the inside.

THE SUGAR PALM.

Arenga saccharifera Labill.

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STARCH OF THE SUGAR PALM.

MALAYAN NAMES.

The name *arenga* is of Javanese origin, the palm being known in that island as *aren* or *areng*. In some parts of the Dutch East Indies it is called *akel*, *lirang* and *cawung* and, on the Malay Peninsula, *kabung*. The Dyak name is *tali idgiok* and the term often employed by the Malays and Indians is *gumuti*. In the Philippines, the most common names are *kaong* (Tagalog), *hibiok* (Visayan), *idiok* (Bikol), and *irok* (on the Island of Mindoro).

Watt⁸⁶ states that this is the sago palm of Malacca and the Malaya, but not the true sago palm. It produces much starch, forming an important article of food among certain tribes of the natives, but this starch is generally inferior to that of the true sago palm, *Metroxylon rumphii* Mart. and other species, found in the Philippines and other parts of Malaya. The starch is spoken of as Java sago.

DESCRIPTION.

The botanical description of the palm is as follows: Clothed above with the fibrous remains of the leaf sheaths. Trunk erect, rather stout, 2 to 12 meters high. Leaves numerous, pinnate, ascending, up to 8 meters in length, the leaflets 100 or more on each side, elongated, 1 to 1.5 meter long, lobed and variously toothed near the apex, the lower surface white. Inflorescence first from an upper leaf axil, and successively from lower ones, the spathes many, clothing the peduncle of the spadix, the

⁸⁶ A Dictionary of the Economic Products of India, Calcutta (1885), 1, 302.

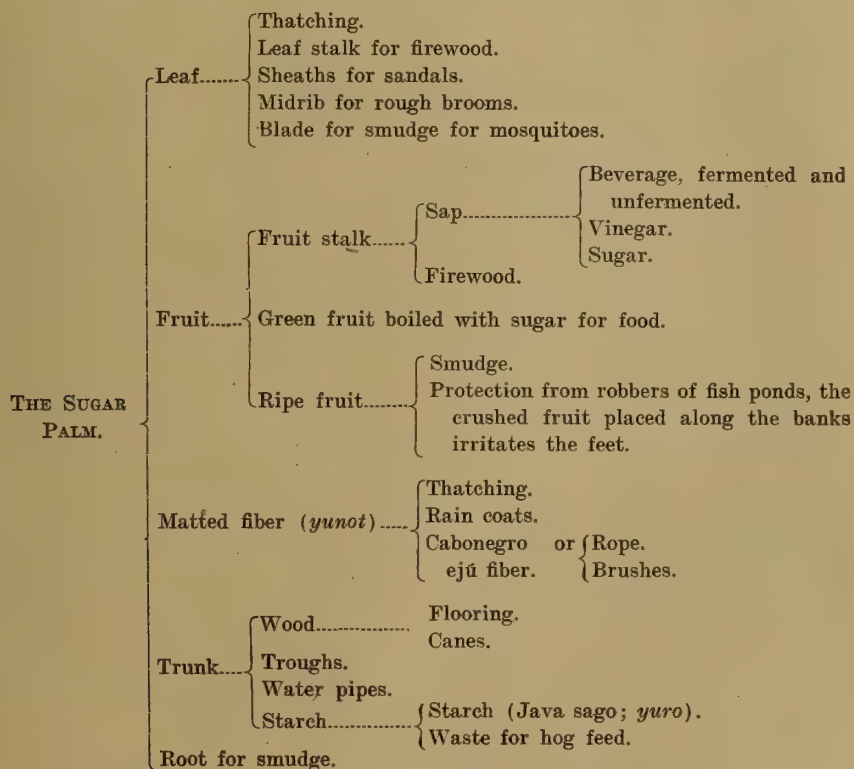
branches numerous, elongated pendulous, 1 to 1.5 meters long. Fruits very numerous, globose, about 5 centimeters in diameter.

DISTRIBUTION.

The palm is found throughout the Philippines at low altitudes, individuals, for the most part, being widely scattered. Some groups of small numbers are reported in Mindanao, Mindoro, and Tayabas.

USES.

At the present time the commercial importance of this palm in these islands is not great. However, it has a large number of uses which have some commercial possibilities. These uses are tabulated as follows:

Uses for the sugar palm.

The fibers and the outside of the trunk, forming a sort of outer bark, are called *cabo negro* (Spanish) in the Philippines and *ejú* or *gomuta* in other parts of Malaya and India. It is used as a thatch and for cables and ropes. This fiber is prized because of its power of resisting decay, and natives have stated to me that the roofs made from it will last for one hundred years. Be this as it may, there is no doubt but that the fiber is in great demand in some sections and is very durable. A roof of about 144 square meters costs, in Laguna Province, at least 50 pesos (25 dollars United States currency) when obtainable. The sap is highly prized by the Filipinos and is drunk both fresh and fermented. Little or none is distilled. Some crude sugar is produced from it, principally on the Island of Mindoro.

THE SAP.

USES.

Watt⁸⁷ states that in Java the palm is chiefly cultivated for its sap, from which a wine, and also sugar and vinegar are prepared, and that the wine is used by the Chinese residing in the Indian islands for the preparation of the celebrated Batavian *arrack*.

The crude process employed in Java for the manufacture of sugar is described by Dr. J. E. de Vry,⁸⁸ as follows:

"As soon as the palm begins to blossom, they cut off the part of the stem that bears the flower; there flows from the cut a sap containing sugar, which they collect in tubes made of bamboo cane, previously exposed to smoke, in order to prevent the fermentation of the juice, which, without this precaution, would take place very quickly under the double influence of the heat of the climate and the presence of a nitrogenous matter.

"The juice thus obtained is immediately poured into shallow iron basins, heated by fire and is thickened by evaporation, till a drop falling on a cold surface solidifies; this degree of concentration attained, the contents of the kettle are put in forms of great prismatic lozenges. Several thousand pounds of sugar are thus obtained yearly."

This writer found the sap to contain sucrose and suggests that it is a logical source of sugar, since the palm thrives upon ground unfit for the production of other crops. He estimates that 0.303 hectare will produce 2,400 kilos of sugar yearly and that the only unfavorable factor is the age which the tree must attain before the yield begins.

Watt⁸⁹ gives the estimate quoted by Simmonds at 6,000 pounds per acre and Jumelle, in speaking of the yield of sago, states that about 400 trees can be

⁸⁷ *Ibid.*

⁸⁸ Watt. *Ibid.*

⁸⁹ *Ibid.*, 92.

planted to the acre and from each tree can be had 154 pounds of sago, giving the enormous total of 61,600 pounds per acre.

Tschirch⁹⁰ describes the uses of the palm in Java and discourages its cultivation for sugar because the production, 8,000 pounds per hectare, is insufficient.

Deon⁹¹ gives an analysis of the sugar produced from the sap of this palm, as follows:

Cane sugar	87.97
Reducing sugars:	
Glucose	1.53
Laevulose	0.18
	1.71
Gum	4.88
Water and volatile matter	1.88
Ash	0.50
Mannite	3.06

Beccari⁹² states that he did not see palm wine extracted from this palm in New Guinea, but that the operation was known and practiced in Papua on the nipa and coconut; and⁹³ in Sarawak, it is noted and appreciated not only for its fermentable liquors and the sugar which can be obtained from this liquor, but also for the strong, black fiber. Beccari⁹⁴ states that the sea Dyaks are much given to the making of feasts to which they dedicate themselves with great enthusiasm. At such times, they give themselves over to interminable ceremonies accompanied by music, song, and banquets, with a profusion of viands interspersed with frequent libations of palm wine and arrak. The first is produced by the fermentation of the saccharine liquor which flows from the cut flowers of *Arenga saccharifera*.

Doctor Foxworthy, of the Bureau of Science, who has recently traveled extensively in Borneo, informs me that in Sarawak, British North Borneo, the sap is rarely used as the beverage *vino de palma*, but that in Sambas, Dutch Borneo, it is more extensively employed.

TAPPING THE PALM.

In order to obtain the sap, the flower stalk is beaten with a small stick or a wooden mallet for a short time on a number of days, sometimes extending over a period of several weeks, in order, probably, to produce a wound tissue. When the proper stage is reached, the stalk is cut off close to the cluster of flowers or

⁹⁰ Indische Heil-und Nutzpflanzen, Berlin (1892), 159-161.

⁹¹ Bull. Soc. chim. Paris (1879), 2, 32, 125.

⁹² Malesia, Genova (1877), 1, 78.

⁹³ Nelle Foreste di Borneo. Firenze (1902), 323.

⁹⁴ Loc cit., 96.

fruit. The sugar sap then begins to flow more or less freely. This process is the same as described in Simmond's Tropical Agriculture.⁹⁵

Molisch⁹⁶ calls attention to the necessity of producing a wound tissue by hammering the flower stalk.

SAP FLOW.

Semler⁹⁷ remarks regarding the flow of sugar sap, that each flower stalk will flow 2 to 4 liters daily for 2 to 5 months.

Molisch⁹⁸ failed to obtain a yield as great as this from the two trees tapped by him. One started with a flow of about 100 cubic centimeters daily, reached a maximum of 2.830 liters in four days, and in eleven days after 18.05 liters had been obtained it ceased to flow. The second tree yielded 29.915 liters in thirteen days, the maximum being 5.400 liters obtained on the sixth day.

I have made no extensive investigations of the sap flow, but found a tree at Nagcarlan, Province of Laguna, from which sap was being obtained by the natives, which gave 2 liters in eight hours during the night. The natives stated that the tree was at that time not producing so well as it had some days previously.

Two flower stalks on two different trees at the Barrio of Sabang near Lucena, Province of Tayabas, were tapped under my direction by two natives who had experience in the work. These palms gave sap for only 25 days. Since only a few samples were collected at irregular intervals, no conclusions can be drawn regarding the total flow. The maximum was at the rate of over 2 liters per day.

COMPOSITION OF THE SAP.

WITH F. AGCAOILI.

The analyses of the samples are tabulated as follows:

⁹⁵ Watt. *Ibid.*, 303. One of the spadices is, on the first appearance of fruit, beaten on three successive days with a small stick with the view of determining the sap to the wounded part. The spadix is then cut a little way from its root (base) and the liquid which pours out is received in pots of earthenware, in bamboos, or other vessels. The Gomuti palm is fit to yield toddy when nine or ten years old, and continues to yield it for two years, at the average rate of three quarts a day.

⁹⁶ *Sitzungsber. Akad. d. Wiss. math.-nat. Klasse*, Wien (1898), 107, 1265.

⁹⁷ *Die tropische Agrikultur*, Wismar (1897), 1, 720.

⁹⁸ *Loc. cit.*

TABLE XXIX.—*Analyses of sap of Arenga saccharifera.*

Tree number 1 at Nagcarlan, Laguna.													
Sam- ple No.	Date collected.	Time of collection.	Amount of flow in cc.	Rate per day in cc.	Density 15° 16°	Total solids in 100 cc.	Ash.	Acidity as acetic.	Sugars.			Remarks.	
									Polar- ization at 30°.	Invert reading at 30°.	Sucrose by Cler-Sucrose get's in 100 cc. mula.		Reduc- ing sugars.
1 ^a	{Jan. 26, 1910	6 p. m.	{-----}	{-----}	1.0500	13.54	0.43	0.02	12.44	-2.71	11.81	12.4	{Average with two samples. Preserved with formalin.
	{Jan. 27, 1910	6 a. m.											
Tree number 2 at Barrio of Sabang, Tayabas.													
1	{Apr. 11, 1910	4 p. m.	{-----}	860	1.0686	16.87	0.34	0.20	6.0	-1.65	5.93	6.3	Preserved with chloroform.
	{Apr. 12, 1910	11 a. m.											
2	{Apr. 13, 1910	{10.35 a. m.	{-----}	660	1.0582	14.67	0.35	0.24	13.0	-2.2	11.78	12.4	Do.
		{6.05 p. m.											
Tree number 3 at Barrio of Sabang, Tayabas.													
1	{Apr. 11, 1910	First flow from flower	{-----}	840	1.0636	17.15	0.37	0.13	9.5	-4.4	10.78	11.5	Preserved with chloroform.
	{Apr. 12, 1910	3 p. m.											
2	{Apr. 13, 1910	{10.50 a. m.	{-----}	550	1.0700	17.59	0.30	0.18	13.0	-2.2	11.78	12.6	Do.
		{6 p. m.											
3	{Apr. 21, 1910	7.40 p. m.	{-----}	120	1.0650	16.76	0.31	0.03	12.0	-3.5	12.03	12.8	Do.
	{Apr. 22, 1910	4 a. m.											

^a A light rain falling for a short time during the night may have diluted these samples to a small extent.

The usual precautions were taken in collecting these samples. The preservative was, in each case, put into the bottle before it was placed in position to catch the sap dropping from the severed flower stalk. It is to be noted that the samples from Tayabas Province show considerably more inversion than those from the tree in Laguna. This is accounted for, in part, by the time which elapsed between the collection of the samples and their arrival at the laboratory in Manila, due to the distance and poor transportation facilities. This, however, does not preclude the possibility of inhibiting the action of the invertase during transit.

From a study of the table it is seen that a fresh sap of the best quality has about the following composition:

Density $\frac{15^{\circ}}{15^{\circ}}$	1.0700
Total solids	17.50
Ash	0.45
Acidity	Trace.
Sucrose	16.50
Reducing sugars	Small amounts or traces.
Undetermined solids	0.55

STARCH OF THE SUGAR PALM.

The natives of certain parts of the islands, principally the Mangyans, a hill tribe of the Island of Mindoro, extract the starch from this palm and use it as a staple article of food. They transport it to the lowlands in baskets of palm leaves (see illustration, Plate XVIII) where it is sold and traded for other articles. I am indebted to Hugo Miller, of the School of Commerce, for the following description of the native method of starch manufacture and for samples of the starch:

"After felling the palm the leaves and bark are removed and the fibrous interior which contains the starch, is chopped into small pieces and worked in water to separate the starch from the fiber. The aqueous fluid, which is now milky in appearance due to starch in suspension, is strained through *sinamay*⁹⁹ or bamboo baskets and conducted through bamboo tubes into settling vessels. The water is drawn off and the starch dried. The starch is light yellow or brown in color, depending upon the degree of purity. Wet pellets of the starch will turn to a kind of sago upon dropping onto hot iron plates."

Photographs of the starch made with polarized and nonpolarized light are shown in Plates XIX and XX.

Analyses of two samples of starch of native manufacture are as follows:

⁹⁹ A stiff, open-weave cloth made in the Philippines; it is composed wholly or in part of Manila hemp fiber.

TABLE XXX.—Analyses of the starch of the sugar palm.

	I.	II.
Moisture.....	10.76	10.25
Ash.....	0.50	0.60
Starch.....	72.02	63.0
Crude fiber.....	1.6	-----

THE OCCURRENCE OF MANNITOL IN PALM SAPS.

Mannitol has been found to be widely distributed in the vegetable kingdom. In *Fraxinus ornus* L. and *F. rotundifolia* Mill., celery (*Apium graveolens* L.), in the leaves of *Syringa vulgaris* L., bark of *Canella alba* Murr., sap of the larch (*Pinus larix* L.), monkshood (*Aconitum napellus* L.), laurel, olive, marine algæ, sugar cane, *Callophisma vitellinum*, many fungi and other plants.¹⁰⁰

Vintilesco¹⁰¹ has found *d*-mannite in *Jasminum officinale* L. and *J. nudiflorum* Lindl., and there is evidence that it exists in *J. fruticans* L.

"The manna which the Israelites are said to have used as bread during their wanderings in the wilderness probably exuded from the branches of the *Tamarix mannifera*, which contains no mannite, but a fermentable sugar, whilst that which fell from heaven probably was edible lichen, *Sparothallia esculenta*, which grows in Asia Minor, Persia, North Africa, etc., and is carried in masses before the wind forming a rain of manna (Luerssen)." ¹⁰²

A number of samples of manna, of various origin, have been examined by Ebert¹⁰³ and he states that none of them contain mannitol.

Mannitol has been found by many investigators in fermented beverages, in fermented onion juice, cider, fig wine, and grape wines.¹⁰⁴

Basile¹⁰⁵ has found that Sicilian wines are subject to an abnormal fermentation, which is some years causes very great loss, the chief product of this fermentation being mannitol produced from the glucose. It is generally the red wines which are attacked rather than the whites, and it is chiefly in hot, dry seasons that this fermentation prevails. In the same cellar and from the same must wines are found varying in mannitol content, side by side, with good, sound wines.

Müller-Thurgau¹⁰⁶ states that mannite is of rather common occurrence in grape wine and he has found it in fruit wines as well. Its development is caused by

¹⁰⁰ Beilstein, Org. Chem., Hamburg u. Leipzig (1893), 1, 284; Erg. (1901), 1, 104; Roscoe and Schorlemmer, Treatise on Chemistry, New York (1898), 3, pt. 2, 484; Meyer u. Jakobson, Org. Chem., Leipzig (1893), 1, 607.

¹⁰¹ Chem. Abstracts (1907), 1, 1605.

¹⁰² Roscoe & Schorlemmer, loc. cit.

¹⁰³ Chem. Abstract (1909), 3, 570; Zeit. Oester. Apoth.-Ver. (1908), 46, 427.

¹⁰⁴ H. and A. Malbot, review of the question. Bull. Soc. Chem., Paris (1894), 11, 87, 176, 413.

¹⁰⁵ Journ. Chem. Soc. Lond. Abs. (1896), 70, 2, 121. Chem. Centralbl. (1894), 2, 498.

¹⁰⁶ Chem. Abs. (1908), 2, 2713.

certain bacteria that transform sugar mainly into lactic and acetic acids. The higher the temperature of fermentation the greater the development of mannite. In all cases the formation of mannite indicates a deterioration of the wine!

Browne¹⁰⁷ states: "The most common fermentation which the raw juice of the cane undergoes in Louisiana, is not alcoholic, as might be supposed, but a fermentation designated variously as viscous, mucilaginous or mannitic. This fermentation is anaerobic in character * * *" and "It was at first supposed that the mannite was the product of a special organism, but this is a mistake, for mannite may be formed in any fermentation of sugar where a reducing action takes place. The quantity of mannite in fermented juices will vary; juices which showed over 2 per cent mannite were found on subsequent analysis to be nearly deficient in the same, owing to the fact that other fermentations had set in whereby the mannite was destroyed."

Balland¹⁰⁸ found 5.6 per cent mannitol in the palm wine from Laghouat, Arabia, made from the sap of a 40-year-old date palm.

Dunstan¹⁰⁹ found approximately 1.8 per cent of mannitol in the water obtained from Ceylon coconuts, while that from a sample of ripe nuts, "as imported into the United Kingdom," contained none. The former, he states, appears to be abnormal in containing mannitol in place of almost all of the glucose usually present.

"It would be interesting to know whether this replacement of glucose and cane sugar by mannitol constantly occurs in nuts grown in Ceylon, or whether it is characteristic of a particular variety of nut. It is worth notice that mannitol is very closely related to glucose, and that it is possible that the presence of mannitol in this sample of 'water,' may be due to a change similar in character to the mannitol fermentation, which occasionally takes place in wine, whereby the sugars normally present in the wine are partially converted into mannitol."

From these considerations it is evident that mannitol will be found to occur in the palm saps which have fermented at the high atmospheric temperatures of this region, 30° and over, where no care has been taken to control the fermentation, even though it may not have been present in the sap as it issued from the tree.¹¹⁰

I have examined a number of samples, over twenty, of the saps of the buri (*Corypha elata* Roxb.), coconut (*Cocos nucifera* Linn.), cabon negro (*Arenga saccharifera* Labill.) and the nipa (*Nipa fruticans* Wurm.) and have found the majority of the samples to be practically free from mannitol, or, at the most, only traces have been present. The largest amounts were encountered where the fermentation of the sap had proceeded to a considerable extent. One sample of the *Arenga* to which formaldehyde had been added as a preservative contained 4.0 per cent of mannitol, which was the largest proportion found. This

¹⁰⁷ *Journ. Amer. Chem. Soc.* (1906), **28**, 459; 462.

¹⁰⁸ *Compt. rend. Acad. Sci.* (1879), **89**, 262.

¹⁰⁹ *Trop. Agr. & Mag. Ceylon Agr. Soc.* (1906), **26**, 377.

¹¹⁰ In this connection it is interesting to recall the equilibrium which has been found by Lobry de Bruyn to exist under certain conditions between glucose \rightleftharpoons fructose \rightleftharpoons mannose.

was isolated, purified and weighed.¹¹¹ After one crystallization from alcohol the characteristic crystals were obtained, melting at 165°. The sample of palm sap, when first analyzed while fresh, and six months later after removing a heavy white precipitate by filtration, had the following compositions:

	Fresh sample.	After fermentation.
Total solids	13.54	7.16
Reducing sugars	0.35	2.86
Alcohol (by volume)	0.00	6.55
Mannitol	-----	4.00
Acidity (as sulphuric)	0.02	0.66
Sucrose	12.4	0.00
Ash	0.43	-----
Undetermined solids ¹¹²	0.34	0.30

The reducing action of the formaldehyde may be responsible for the high per cent of mannitol.

Of the other samples which contained mannitol the next largest amount was 0.3 per cent and in a few cases smaller amounts were detected.

No evidence has been obtained which points to the existence of mannitol or mannose in the fresh palm saps, in any appreciable quantities. Abnormal cases may exist where mannitol or the related sugar may occur in these saps in larger amounts.

¹¹¹ Mannitol was also isolated, as a check upon other methods employed, by the process of Guignet (*Compt. rend. Acad. sci.* (1889), **109**, 528.) Also described by Browne (*Journ. Amer. Chem. Soc.* (1906), **28**, 462) with very satisfactory results.

¹¹² A considerable portion of the undetermined solids is composed of nitrogenous compounds.

ILLUSTRATIONS.

PLATE IX.

The coconut palm. Infra red photograph by Gibbs.

PLATE X.

A small grove of coconut trees. Luisiana, Province of Laguna. The bamboo bridges reaching from tree to tree are well shown. (Photograph by Martin.)

PLATE XI.

Near view of a coconut grove. Luisiana, Province of Laguna. On the left side of the trunk on the level of the native's head almost hidden by the leaf stems, is hung a bamboo joint, attached to a flower stalk, for collecting the sap. The bamboo bridges from tree top to tree top facilitate the collection of the sap. By climbing one tree the tops of many others are thus made accessible. (Photograph by Martin.)

PLATE XII.

Distillery at Luisiana, Province of Laguna. (Photograph by Martin.)

PLATE XIII.

FIG. 1. Distillery at Majayjay, Barrio Bangalan, Province of Laguna. The still condenser and fire box are shown. (Photograph by Gibbs.)

2. Distillery at Nagcarlan, Province of Laguna. The still, condenser, and earthen jars for tuba are shown. (Photograph by Gibbs.)

PLATE XIV.

The buri palm. Infra red photograph by Gibbs.

PLATE XV.

Buri palms tapped for their sap. The cone of leaves protecting the cut surface on top is well shown. The thatch houses are typical native homes. (Photograph by Martin.)

PLATE XVI.

FIG. 1. Buri palm. Marilao, Bulacan Province. See tree number 1, Table of analyses. The man standing on the top gives a good idea of the size of the tree. (Photograph by Gibbs.)

2. Starch from the buri palm. $\times 75$.

PLATE XVII.

Arenga saccharifera Labill. Two large inflorescences are shown, one very clearly exposed on the near side of the tree. (Photograph by Gibbs.)

PLATE XVIII.

Basket of sugar palm starch.

PLATE XIX.

Starch grains of the sugar palm. Photograph by nonpolarized light. $\times 120$.

PLATE XX.

Starch grains of the sugar palm. Photograph by polarized light. $\times 120$.

TEXT FIGURES.

Map No. 2. Showing distribution of the coconut palm in the Philippine Islands.

FIG. 3. Young inflorescence of coconut palm. (a) Base of the flower stalk. (b) Cut end from which the sugar sap flows. (c) Female flower. One-seventh natural size. (Molisch.)

Map No. 3. Showing distribution of the buri palm in the Philippine Islands.

FIG. 4. Diagram of the curves for the inversion, and alcoholic and acetic acid spontaneous fermentations of the buri palm sap.

5. Diagram showing the sap flow, per cent Brix and sugar yield of the sap of the buri palm.



PLATE IX.



PLATE X.



PLATE XI.

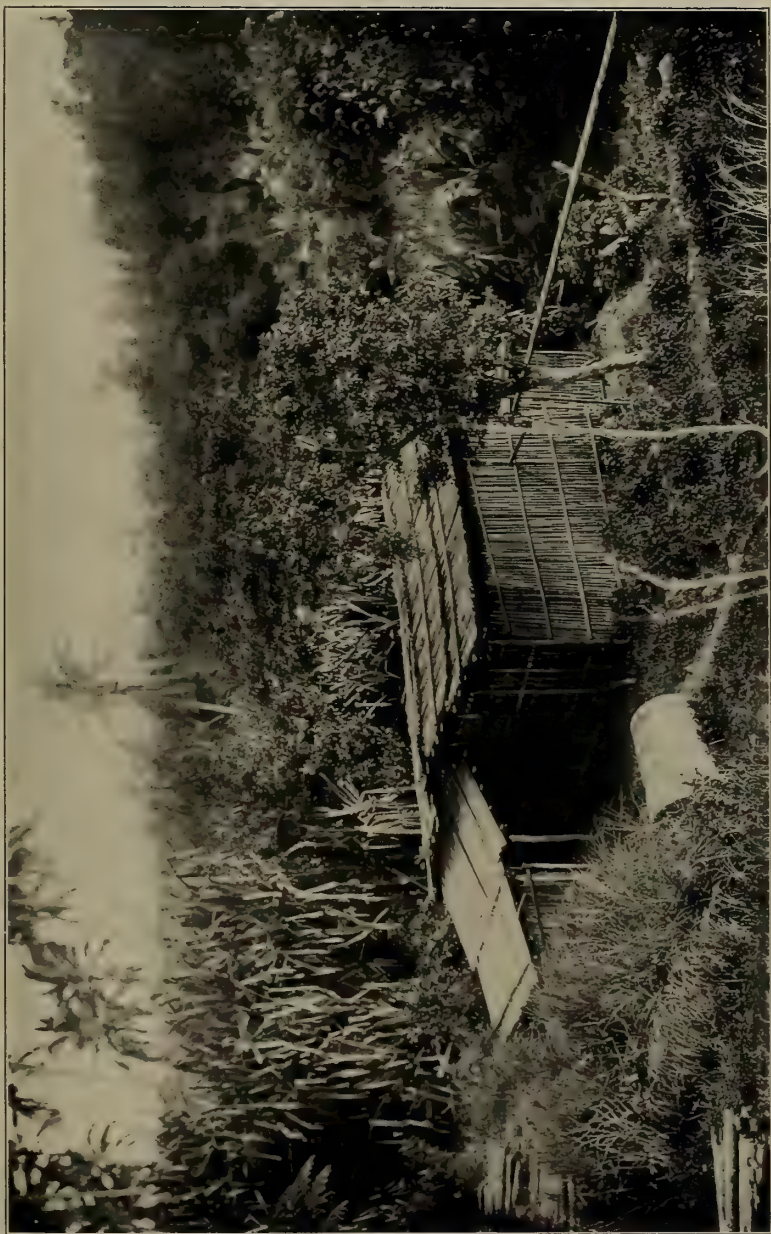


PLATE XII.

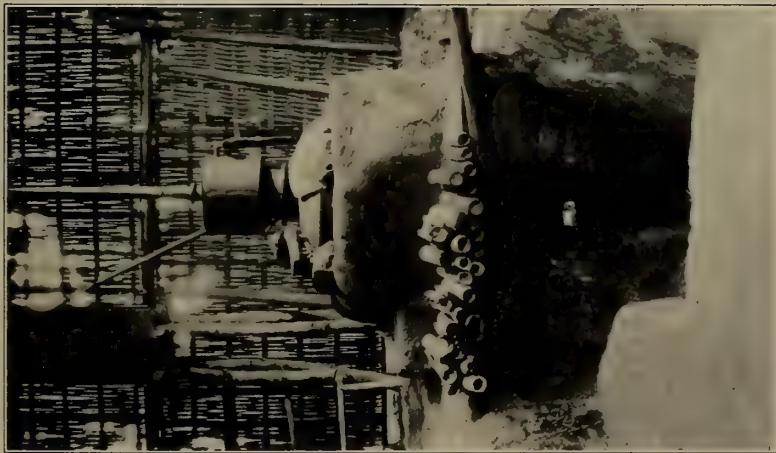


FIG. 1.

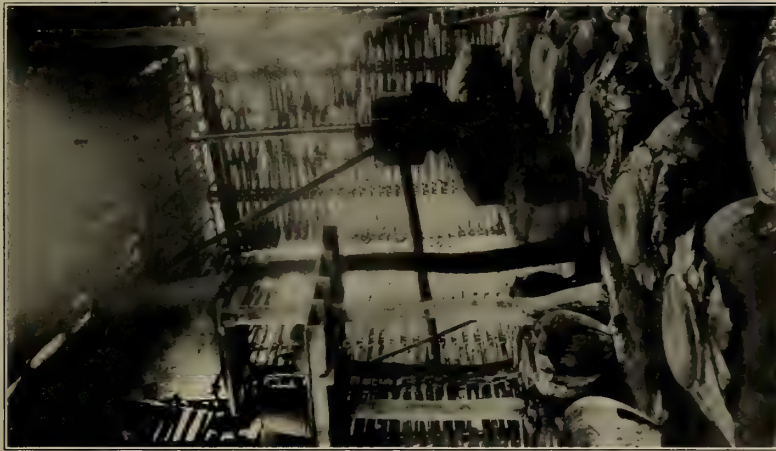


FIG. 2.



PLATE XIV.



PLATE XV.

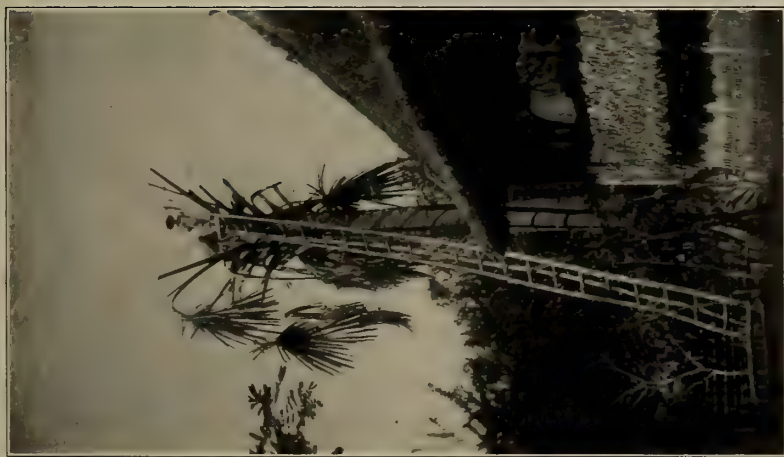


FIG. 1.



FIG. 2



PLATE XVII.



PLATE XVIII.

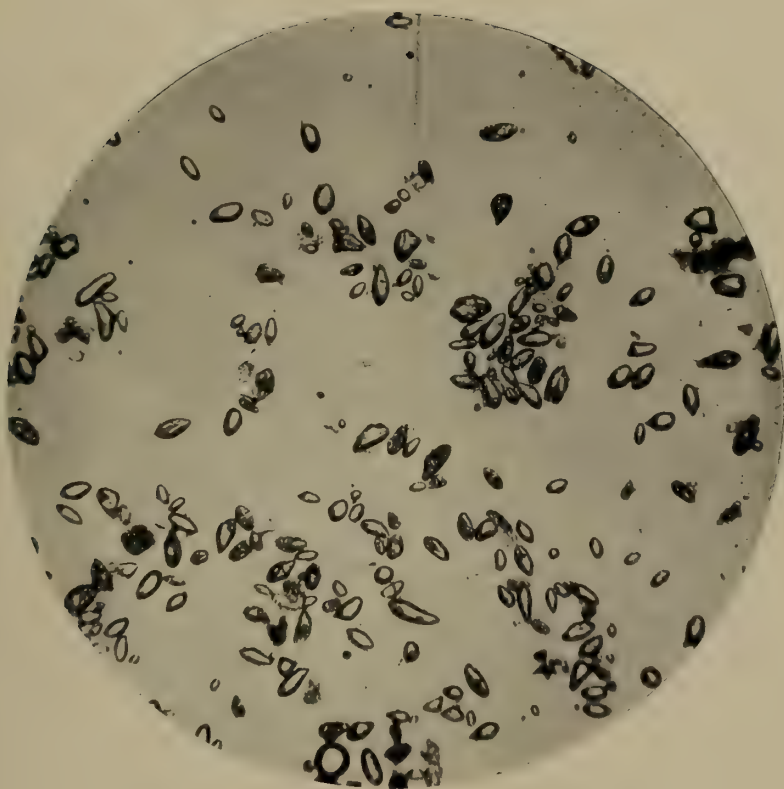


PLATE XIX.

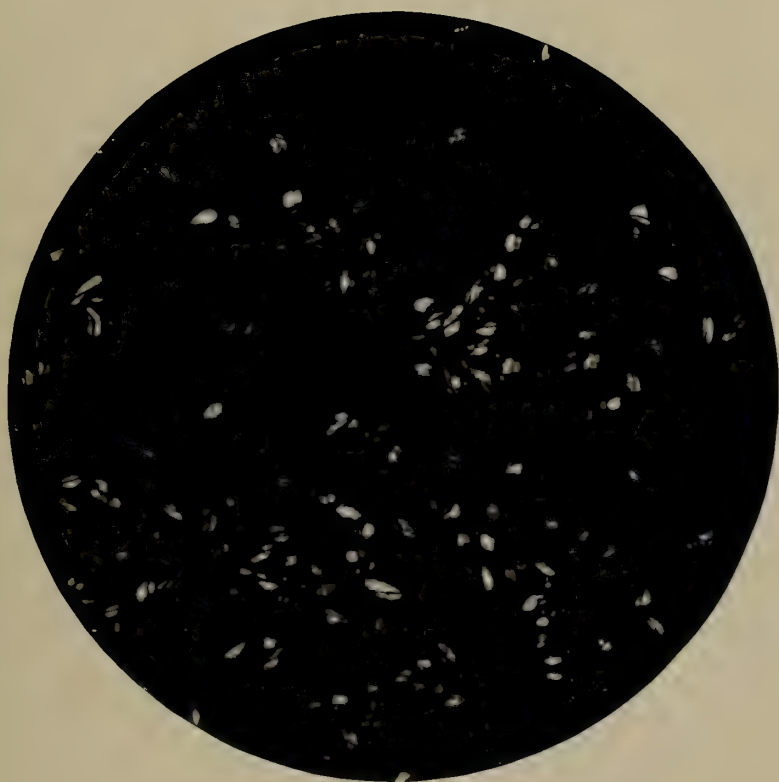


PLATE XX.

PHYSICAL AND CHEMICAL PROPERTIES OF PORTLAND CEMENT. PART III.

By W. C. REIBLING and F. D. REYES.

(From the Laboratory of General, Inorganic and Physical Chemistry, Bureau of Science, Manila, P. I.)

THE SETTING PROPERTIES OF PORTLAND CEMENT.

GENERAL CONSIDERATIONS.

A study of the important hardening properties of Portland cement concerns itself with two essentially different processes. The preliminary one by which the soft or plastic paste is converted into a friable mass is termed the "setting" and is so distinguished from the subsequent "hardening," which is slow, long continued, and practically permanent.

Experience has shown that the efficiency of Portland cement is vitally affected by the way in which it sets, and although manufacturers are now producing a product which is rapidly becoming more and more uniform, certain Portland cements are still encountered the setting properties of which are erratic, undesirable and at times even dangerous. The manufacturer usually succeeds in making a cement which sets normally, but he often fails to produce one which will remain so under all ordinary conditions of storage. Therefore, it frequently happens that a cement develops unsatisfactory setting qualities after it has left the mill. Unfortunately, when this occurs, so little is known of the phenomena which have caused the change that it has often proved impossible to find a remedy against its recurrence. The practical problem in this respect, therefore, concerns itself essentially with the control of the set.

Scientific knowledge on the subject has remained very limited and indefinite, because of the experimental difficulties in isolating and identifying hydraulic compounds which decompose or become altered on contact with water, and the individual particles of which are largely sub-microscopic. Research work, founded on observations of physical changes have only served to supply the manufacturer with contradictory and inexplicable data. We believe this to be due to a somewhat general misconception of the true nature of Portland cement, the investigators

either failing to recognize the indefinite composition of the product, or neglecting entirely properly to ascertain or consider the nature and significance of changes in physical and chemical properties which different methods of seasoning induce. A few observations will demonstrate our reasons for this belief and suggest as well certain facts a careful consideration of which, it is thought, would lead to more definite results.

The fact that the calcareous hydraulic cements do not represent well defined compounds, but mixtures of calcium aluminates, calcium ferates and calcium silicates, with varying amounts of uncombined calcium oxide, must be regarded as having been conclusively proved from the laborious and thorough synthetic work of Dr. O. Schott⁴⁰ and the analytical studies recorded in Parts I and II⁴¹ of this paper. Furthermore, we have shown that in non-seasoned cement uncombined lime may have different physical properties according to the duration and degree of heat to which it has been subjected during the process of burning and that in the seasoned commercial cement the uncombined lime may exist partially or wholly in the sintered, non-sintered, slaked and crystalline, and slaked and amorphous states, and combined as inert calcium carbonate. Since synthetic work has shown that calcium oxide, hydroxide and carbonate, each effect the physical properties of Portland cement in a different manner, it is evident that properly to study the changes produced during the seasoning of Portland cement, it is essential to note those which occur in the condition of the free lime which may be present.

With these facts in mind we have endeavored to select from the mass of literature on this subject conclusions which appear to be the most reasonable, or which otherwise require consideration.

The exact nature of the phenomena involved and of the compounds causing the setting of Portland cement are still matters more or less of theory. According to Le Chatelier the early hardening of Portland cement is due to a deposit of interlocking crystals of hydrated calcium aluminates separating from a super-saturated solution. He further states that only those varieties of hydrated calcium aluminate which are permanent in the presence of an excess of lime-water need be considered in connection with the set of cement.

Whether we accept this theory or not, we must admit that the set is caused by the presence of certain compounds in Portland cement the quantity, composition and activity of which are not revealed by chem-

⁴⁰ The Calcium Silicates and Calcium Aluminates contained in Portland Cement. (1906).

⁴¹ *This Journal*, Sec. A (1910), 5, 367-418.

ical analysis. This conclusion is strengthened by the work of E. D. Campbell.⁴²

This author heated calcium oxide and marl in his experimental furnace, and found that "when calcium oxide is heated with calcium aluminate, probably the dicalcium aluminate is first formed, this formation being completed at about 1,200°. Further, that dicalcium aluminate which may be completely formed above 1,200° then begins to combine with more alumina, if present, as the temperature increases, until monocalcium aluminate has been formed at 1,400°. The dicalcium aluminate when completely formed * * * has a quick initial and a quick final set, even when the material has been partially fused. The proportion of dicalcium aluminate and monocalcium aluminate existing at any given temperature will be largely influenced by the relative masses of the two oxides." Campbell's work also indicates that ferric oxide behaves very much as alumina, both in chemical and physical properties, but in the light of Unger's more recent researches we may carry the discussion still farther.

The Portland cement which he fused in an electric furnace contained all of the iron in the form of the lower oxide. This was contrary to Loebell's experience with vitrified Portland cement, which showed that almost all of the iron was present in the form of ferric oxide.

W. Michaelis, jr.,⁴³ concludes from these experiments that Unger's fused Portland cement containing, as it does, the oxide of iron in the ferrous state differs from the commercial product because the iron oxide acts as a base thereby differing from the oxide in the vitrified product where it has acid properties. Unger's fused cement hardened very slowly and imperfectly whereas the same mixture burnt only to the point of vitrification, hardened rapidly.

As nothing more definite is known concerning the chemistry and mechanics of this subject, the manufacturer, in the beginning, has no recourse other than actual experimentation. Some raw mixtures if burned to a hard, homogeneous clinker produce a cement of quick-setting properties which it may be impossible to retard. Other raw mixtures must be burned to a hard, homogeneous clinker in order to produce a cement capable of a normal set. The very nature of the burning processes employed renders it doubtful if the successful manufacture of Portland cement will ever depend upon anything more definite than control by rule of thumb methods. However, if Portland cement were to be ground from a perfectly fused mass, instead of from sintered clinkers, there is little doubt that its chemical and physical properties could soon be as accurately and scientifically controlled as the manufacture of iron and steel.

As it is, a number of factors, influencing the chemical and physical conditions of the compounds involved in the setting of Portland cement, must be taken into consideration. These are: (1) The amount of water used. (2) The temperature of the water and the surrounding

⁴² *Journ. Am. Chem. Soc.* (1904), 26, 1152.

⁴³ *Cement and Engineering News* (1910), 22, 8, 327.

atmosphere. (3) Impurities in the water. (4) The fineness of the cement. (5) The retarders added to the cement. (6) The time and manner of curing and storing it. (7) The quantity and the condition of the free lime. (8) The temperature of the freshly molded cement paste.

The first three factors can be so carefully regulated as to render their influence practically constant. The influence of the others is less definite. They are interdependent and generally speaking but little understood.

The peculiar effect of gypsum or plaster of Paris upon the setting properties of Portland cement has received much attention and many theories have been proposed to explain its action. Of these we mention only two.

Dr. Rohland ascribes it to catalysis, considering calcium sulphate to be a catalytic retarder. Candlot concluded that gypsum added to Portland cement produces a double salt of basic calcium aluminate and sulphate. He believed that he succeeded in producing this salt artificially.

It would seem as if the action of gypsum was capable of a simpler explanation than those already advanced. The salt is soluble in water to the extent of 1 part of calcium sulphate to 490 parts of water at 15°. In dissolving it is ionized and obviously the addition of calcium ions would reduce the solubility of the other calcium ions already present. The free lime would therefore be less rapidly dissolved and the hydrolysis of the aluminates would be retarded, the result being a slowing of the set. As the free lime changes to calcium carbonate it is removed from solution and becomes inert. The loss of these calcium ions of course increases the solubility of the aluminates and the facility with which they hydrolyze, the result being a quickening of the set.

However, whatever the nature of this action, Candlot's experiments show very conclusively that the presence of slaked lime increases the efficiency of sulphates of calcium as retarders. His conclusions in this respect were verified in the mechanical laboratory of Sibley College, Cornell University. Experiments in the chemical laboratory of the Bureau of Science have resulted in similar observations.

The sixth factor mentioned above, namely the time and method of curing, is dependent upon changes brought about by air and moisture. According to Candlot the change in the setting properties which sometimes occurs when cements are stored is due to the formation of calcium carbonate.

However, we do not believe that the change of the slaked lime in Portland cement to calcium carbonate is the usual or universal cause of changes in setting properties. Such changes have been known to take place within a few days in cements stored in paper-lined barrels or in

covered bins and consequently the lime could have had very little opportunity to combine with carbon dioxide, because our previous work shows that only the exposed surface of packed cement is able to do so. Furthermore, it requires very thorough and prolonged aëration to change all of the slaked lime to calcium carbonate in the commercial products usually received.

The influences given under 7 and 8, therefore, alone remain to be discussed. In carrying on this work we continued our study of the test for free lime⁴⁴ and by this means we have found that all changes in the setting properties of Portland cement can readily be accounted for.

Our experiments on this subject have also furnished some instructive data concerning the plastic and other physical properties of Portland cement. We believe that they show conclusively that in the majority of instances the setting properties of extremely finely ground cements may be as easily controlled as when the same material is coarsely ground; and that they furnish an explanation of the beneficial effects derived from grinding Portland cement in the presence of live steam. We also believe that these experiments will enable the manufacturer so to control the setting properties of his cement that it will remain normal under all ordinary conditions of storage. Unfortunately, the work which follows, although presented as an abstract of the results obtained, is necessarily somewhat lengthy because of the complicated nature of the subject under discussion.

THE METHOD OF ASCERTAINING THE SETTING PROPERTIES.

Throughout our work, several standard methods were employed for determining the time of the initial and final set. The method employing the Vicat needle as adopted by the American Society for Testing Materials was found to be the most consistent with the manner in which cement is used in actual work. It is reliable, impartial and accurate.

However, the method of the Vicat needle, like all others, has met with severe criticism. For instance, Russel S. Greenman⁴⁵ states that the percentage of water required to produce a paste of normal consistency varies from 18 to 28 per cent; that the results obtained are as varied as could be imagined; that some cements frequently fail to produce a required penetration of 10 millimeters unless the cement is flooded with water; and so forth.

Although our experience has often been similar to that of Greenman, we believe his criticism should be applied to the cement itself,

⁴⁴ *This Journal, Sec. A* (1910), 5, 367.

⁴⁵ *Proc. Am. Soc. Test. Materials* (1906), 6, 355.

and not to the method employed in testing. We have found that the testing of properly seasoned cements of the best manufacture does not necessitate such variations. With good cements, a plastic paste of normal consistency is readily obtained with from 19 to 23 per cent of water, and competent testers readily secure concordant results, serious discrepancies occurring only when outside influences had brought about changes in the setting properties of the cement before the tests were made.

Portland cements which requires 28 per cent of water, or which can not readily be gauged into a plastic paste of normal consistency without flooding them with water, deserve no further consideration as they will also lack in sand-carrying capacity and troweling properties and, therefore, will be but poorly adapted to meet the modern requirements of reinforced concrete.

It is also evident that a cement, the development of the setting properties of which can not be controlled within reasonable limits by the carefully regulated conditions imposed by this test, can not be guaranteed to give satisfactory service under the variable conditions met with when it is to be used for construction work.

It also has been stated that no standard method for determining the rate of set really measures the exact time of the beginning or ending of this early process of hardening. This is true, but fortunately the setting properties of Portland cement become a consideration of paramount importance only when the set is abnormally quick or abnormally slow. In quick-setting cements the process when once it begins proceeds to completion very rapidly. The cement can harden but very little when the Vicat needle method is employed, before the set needle ceases to penetrate the required distance. Therefore quick, normal and extremely slow-setting cements are readily identified by this method, and for all practical purposes no more accurate determination is necessary.

However, it sometime happens that the cement paste held in the conical, hard-rubber ring of the apparatus fails to harden equally throughout its mass. It also is impossible to eliminate air bubbles from the neat mortar. Therefore, in our research work when the greatest accuracy obtainable was desired, we took the average of three penetrations of the set needle which was applied at points equidistant from the center and the circumference of the upper surface of the cement so as to form the points of an equilateral triangle.

At times the cement was also gauged by different methods, of mixing and by various amounts of water. Owing to the heat usually liberated by setting cements, the practice of storing the test specimens in one compartment of a moist air closet is very liable to cause abnormal results. To avoid this risk, we placed the gauged cement in isolated compartments especially constructed for this purpose.

Experiments which produced important results were repeated from time to time in order to insure their freedom from personal error and from the effect of slight changes in atmospheric conditions. Unless otherwise stated, only those results which were free from slight changes in the working conditions are recorded.

GENERAL OBSERVATIONS CONCERNING CHANGES IN THE RATE OF SET.

A series of experiments showing remarkable changes which occurred in the setting properties of certain cements after a few days of exposure to the atmosphere have been published from this laboratory⁴⁶ and in the same paper it was shown that the set of other cements, aged in the same manner and at the same time, and of the same cements stored in tightly covered cans, remained practically constant.

These experiments led us to believe that a similar, but a more thorough study of the behavior of many brands of the commercial product might lead to definite conclusions. Accordingly, all of the cements of Table A⁴⁷ were aged in three ways. They were stored in sealed bottles, in open, coverless cans and in shallow pans,⁴⁸ from time to time changes in the plastic or setting properties were carefully noted.

As this work progressed it soon became apparent that the variations primarily depended on the manner in which the cement had been stored. In this respect the data in Table XX are characteristic of the whole series of experiments.

Little or no change is shown in the setting of the cements kept in sealed bottles and in no instance did a set change from quick to slow, or *vice versa*. Experiments in the cement laboratory of the Bureau of Science demonstrate that only cements which contain considerable amounts of free moisture are apt to be changed materially when aged

⁴⁶ *This Journal, Sec. A* (1908), 3, 137-186.

⁴⁷ *Ibid.* (1910), 5, 414.

⁴⁸ In the latter case about 30 kilograms of cement was spread over the bottom of a pan in a layer about 6 centimeters deep, the cement being thoroughly mixed twice each day for three days and once daily thereafter.

TABLE XX.—The plastic and setting properties of the same cement aged and tested at the same time, but stored differently.

Num-ber.	Temperature of the laboratory during the gauging and setting of the cement.	Stored in sealed bottles.						Stored in coverless cans.						Stored in shallow pans and frequently removed.						
		Specific gravity.	Per cent of water required to form a paste of normal consistency.	Time of setting.				Specific gravity.	Per cent of water required to form a paste of normal consistency.	Time of setting.				Specific gravity.	Per cent of water required to form a paste of normal consistency.	Time of setting.				
				Initial.	Final.	Hours.	Min-utes.			Initial.	Final.	Hours.	Min-utes.			Initial.	Final.	Hours.	Min-utes.	
1	30° -31° 5	0	3.09	21.0	1	15	2	40	3.090	21.0	1	15	2	40	3.090	21.0	1	15	2	40
3	27° 5-30° 5	4	3.09	21.0	1	25	2	45	3.075	20.0	1	25	2	50	3.070	19.0	0	45	1	30
6	27° 5-30° 5	18	3.09	21.0	1	20	2	35	3.050	20.5	1	40	4	30	3.045	20.8	1	30	4	30
12	28° 5-30° 5	42	3.09	21.0	1	20	2	30	3.030	20.5	2	0	3-	50	3.030	22.0	0	15	0	55
18	29° -31°	95	3.09	21.0	1	35	2	55	2.990	21.5	2	0	4	40	2.950	25.0	2	10	7+	-----

in this manner. Such alterations have been reported by several other investigators, but in each instance no mention is made of the amount of uncombined water which was present in the cement before and after the changes had occurred.

The results obtained with cements stored in coverless cans and allowed to remain undisturbed until tested, correspond with the information recorded in Tables IX, X, and XI; the cement near the top proved to be essentially different from that taken 25 millimeters or more below the surface. Mixtures of cement seasoned in this manner sometimes developed a considerable variation in physical properties, but it is obvious that figures obtained from such mixed material are too complicated for analytical treatment.

A careful consideration of the character of the absorption curves given in figures 12 and 13 shows that this difficulty can be overcome to a large extent by aërating the cement in large, shallow pans. This method also prevented the caking of the cement. The plastic and setting properties of the cement treated in this manner changed decidedly, and eventually became abnormal, but the alterations in this respect followed no apparent rule. Some normal cements soon became decidedly quick setting. A few of these promptly again acquired a slow set, but the majority remained quick setting until the cement became almost inert from prolonged aëration. Others at first set more slowly and then more rapidly. One sample of brand O showed four distinct variations. Its set changed first from slow to quick, then to slow, again to quick, and finally, back to slow. Eventually, after prolonged aëration, all of the materials became so inert that they set very slowly. This was especially true of that which had been finely ground. Such cement at times failed to harden perceptibly within a week or more. Then again, the set of some samples remained more constant than that of others; so that an investigation was made to ascertain whether the chemical composition had any bearing upon the stability of the latter.

These results and the work already discussed in Parts I and II of this paper, make it evident that changes in the physical properties of Portland cement are due primarily to the absorption of water or water and carbon dioxide. Therefore, the influences of chemical composition presumably could definitely be ascertained, if the changes in the character of the set of a cement which is undergoing thorough aëration were to be considered carefully, in conjunction with the amount of water and carbon dioxide absorbed, the fineness of grinding, and the amount of retarder employed.

A few examples recorded in Table XXI, demonstrated that the character and the stability of the set were independent of the ultimate chemical composition, the fineness and the amount of retarder.

TABLE XXI.—Chemical and physical properties of several commercial Portland cements chosen to show that the rate of setting is independent of the ultimate chemical analysis, fineness and amount of retarder.

Ultimate chemical analyses of commercial Portland cements.																									% SiO ₂ , Al ₂ O ₃ , MgO or CaO—0.7 × % SO ₃ , 100—% loss on ignition + (1.7 × % SO ₃).	
Number.	Brand.	Moisture at 110°.	Loss on ignition.	Insoluble residue.	Nature of insoluble residue.	CO ₂ .	Undetermined.	Total SiO ₂ .	Combined SiO ₂ .	Al ₂ O ₃ .	Fe ₂ O ₃ .	Total CaO.	CaO in gypsum.	CaO in carbon-ate.	Total CaO—(CaO in gypsum and carbonate).	MgO.	Column 14 plus MgO.	SO ₃ .	Total SiO ₂ .	Al ₂ O ₃ .	Fe ₂ O ₃ .	Available CaO.	MgO.	Available CaO + MgO.		
1	O	0.26	2.14	0.68	Free silica	0.51	1.44	20.11	19.43	7.25	4.02	62.24	1.00	0.65	60.59	1.36	61.95	1.44	21.00	7.60	4.21	64.26	1.42	65.67		
2	O	0.27	2.20	0.41	do	0.34	0.98	19.80	19.39	8.66	2.67	62.56	0.82	0.43	61.31	1.96	63.27	1.17	20.63	9.05	2.78	64.45	2.04	66.49		
3	O	0.41	2.47	0.71	do	0.40	0.64	20.65	19.94	8.57	3.07	61.83	0.36	0.51	60.96	2.26	63.22	0.51	21.35	8.86	3.17	63.50	2.34	65.84		
4	K	0.39	1.03	0.40	do	0.14	1.39	24.28	23.88	4.48	2.38	63.96	0.81	0.18	62.97	1.32	64.29	1.16	25.00	4.62	2.45	65.00	1.36	66.36		
5	M	0.28	1.47	1.45	do	0.12	0.25	23.21	21.76	4.60	3.93	64.22	0.98	0.15	63.09	0.92	64.01	1.40	24.15	4.78	4.08	65.75	0.95	66.70		
6	O	0.57	1.69	2.00	do	0.32	0.76	23.80	21.80	7.72	2.01	61.83	1.02	0.41	60.40	0.74	61.14	1.45	24.85	8.06	2.10	63.60	0.78	64.38		

Number.	Brand.	Condition.	1	2	3	4	5	6	7	8	9	10	Fineness, per cent.		Specific gravity.	Per cent of water required for a paste of normal consistency.	Temperature of laboratory.	Time of setting.			
																		Initial.		Final.	
													200-mesh sieve.	100-mesh sieve.				Hours.	Minutes.	Hours.	Minutes.
1	O	Cement ^a {Clinker ^b	2.68 2.77	1.72 1.78	1.97 1.95	2.32 2.29	7.58 7.07	2.73 2.68	62.42 67.40	66.85 72.05	50.55 55.35	54.30 59.56	78.2	95.5	3.11	22.0	28-30	0	15	0	25
2	O	{Cement ^a {Clinker ^b	2.24 2.29	1.71 1.74	2.00 1.98	2.26 2.24	7.85 7.55	2.49 2.47	63.80 67.70	66.74 70.78	51.96 55.60	63.63 58.38	78.0	96.0	3.09	20.5	28-30	1	20	2	40
3	O	{Cement ^a {Clinker ^b	2.33 2.41	1.71 1.77	1.93 1.90	2.22 2.18	7.82 7.07	2.48 2.44	65.33 69.59	68.60 72.98	53.82 57.36	55.39 60.53	76.5	95.0	3.07	20.0	28-30	0	25	0	45
4	I	{Cement ^a {Clinker ^b	2.33 5.42	3.03 3.54	2.04 2.03	2.27 2.24	3.78 3.70	2.48 2.44	71.84 75.09	74.45 77.82	59.98 63.02	61.36 65.47	87.0	97.8	3.13	20.0	28-30	1	40	4	50
5	K	{Cement ^a {Clinker ^b	4.73 5.04	2.55 2.73	2.08 1.99	2.43 2.31	4.84 4.36	2.85 2.68	66.01 72.80	70.33 76.30	54.15 60.83	57.08 64.91	89.0	99.0	3.12	24.0	28-30	0	10	0	30
6	Y	{Cement ^a {Clinker ^b	2.82 3.08	2.24 2.44	1.91 1.82	2.07 1.96	5.06 4.38	2.22 2.09	69.54 78.36	71.73 80.63	59.32 66.06	60.33 68.16	78.8	96.4	3.10	25.0	28-30	0	8	0	15

^a The figures obtained from the analyses of these cements are considered from two standpoints: (a) The oxides which have entered into combination to form the hydraulic compounds, and (b) the oxides which might have been available in the raw meal used for the formation of hydraulic compounds. The former (a) can only be approximated; but as it is known that these cements were treated with gypsum and that the carbon dioxide which they contain is united with calcium oxide, the values of the formulas (see columns 1 to 10) given under (a) were obtained after subtracting $0.7 \times \text{SO}_3 + 1.27 \times \text{CO}_2$ from the total calcium oxide, and likewise subtracting the free from the combined silica.

^b In order to ascertain the oxides originally present in the clinker, the volatile constituents and the gypsum must be eliminated. The formula for so doing is $\frac{\text{Per cent } \text{SiO}_2, \text{Al}_2\text{O}_3, \text{Fe}_2\text{O}_3, \text{MgO, or total CaO} - 0.7 \times \text{SO}_3}{100 - (\text{per cent loss by ignition} + 1.7 \text{ per cent } \text{SO}_3)}$

The silica, alumina and iron oxide from the fuel may or may not have combined with the calcium oxide in the raw meal, and therefore consideration of this fact is given by formulas of columns 9 and 10. The possibility of magnesia acting as lime and iron oxide as alumina has also been included in the diagnosis of these cements.

We also were unable to obtain more definite information as to the probable setting qualities by taking into consideration the nature of the raw materials used or the burning processes employed. Our knowledge in this respect is somewhat limited, but the evidence given in Table XXII is sufficient to justify the conclusion that if we consider the setting properties of Portland cements, there is no characteristic belonging to them which necessarily would indicate that the cement had been manufactured by any certain process of burning or from any definite class of raw materials.

TABLE XXII.—Changes in physical properties produced by thoroughly aerating standard Portland cements.

Number.	Description.	Variation in temperature during gauging and setting.	Time of aëration in days.	Specific gravity.	Per cent of water required for a paste of normal consistency.	Setting time.			
						Initial set.		Final set.	
						Hours.	Minutes.	Hours.	Minutes.
Cements made from hard mountain limestone and clay by the set-kiln process.									
1	Brand "X."	25.5-29.0	0	3.06	20.0	1	10	2	50
	Fineness=86.8 and 97.3 per cent. Loss by ignition=2.70 per cent. Per cent of SO ₃ =2.16.	25.5-27.5	3	3.045	21.8	3	0	6	0
		26.0-30.5	7	2.99	22.0	1	30	6	0
		25.2-27.0	28	2.97	24.5	0	40	1	10
		26.0-28.5	60	2.92	28.0	1	15	2	40
	26.0-28.5	270	2.807	39.0	105	×	552	×	
	2	Brand "L."	26.5-30.0	0	3.12	21.0	2	30	7	0
Fineness=75.0 and 93.0 per cent. Loss by ignition=2.52 per cent. Per cent of SO ₃ =0.60.		26.5-30.0	3	3.10	19.5	2	0	6	10
		25.0-29.0	7	3.08	20.0	3	0	5	30
		26.0-30.0	14	3.07	21.0	2	0	6	20
		26.0-28.0	28	3.04	22.0	0	8	6	0
25.5-30.0		30	3.04	22.0	0	15	6	30	
26.0-30.0		60	2.99	23.0	2	30	7	0	
26.0-30.0		90	2.90	24.0	3	10	8+	×	
26.0-28.5		270	2.857	30.0	7	×	144	×	
Cement made from hard mountain limestone and clay by the rotary process.									
3	Brand "G."	26-28.0	0	3.10	19.0	2	0	6	20
	Fineness=79.2 and 93.0 per cent. Loss by ignition=2.10 per cent. Per cent of SO ₃ =1.37.	26-30.0	15	3.08	21.0	1	30	4	30
		27-30.0	35	3.06	21.0	2	0	5	30
		27-30.0	50	3.048	22.0	2	30	5	0
		27-28.5	60	3.046	22.5	2	20	5	0
		27-28.0	90	2.99	24.0	3	10	8-	×

TABLE XXII.—Changes in physical properties, etc.—Continued.

Number.	Description.	Variation in temperature during gauging and setting.	Time of aëration in days.	Specific gravity.	Per cent of water required for a paste of normal consistency.	Setting time.			
						Initial set.		Final set.	
						Hours.	Minutes.	Hours.	Minutes.
Cement made from hard mountain limestone and clay by the rotary process.									
4	Brand "O."	27-30.0	0	3.094	22.0	1	20	2	30
	Fineness=78.0 and 96.0 per cent. Loss by ignition=2.94 per cent. Per cent of SO ₃ =1.19.	27-30.0	5	3.08	19.0	0	50	1	30
		26-29.0	21	3.07	20.8	1	30	4	30
		27-30.0	33	3.04	21.0	1	10	3	40
		26-29.0	42	3.03	22.0	0	25	1	10
		27-28.5	77	2.962	23.0	0	35	0	45
		27-28.5	90	2.955	24.5	1	5	2	0
		Cement made from cement rock by the rotary process.							
5	Brand "N."	28.0-30.0	0	3.115	21.0	1	0	2	0
	Fineness=76.4 and 96.0 per cent. Loss by ignition=1.58 per cent. Per cent of SO ₃ =1.80.	28.0-30.0	3	3.08	21.0	2	35	4	30
		27.5-29.5	9	3.04	20.0	1	40	3	30
		27.5-31.0	16	3.026	20.0	1	20	4	0
		27.5-31.0	23	3.004	21.0	1	40	4	30
		26.5-28.0	30	2.962	22.0	0	30	3	0
		28.0	35	2.942	22.5	0	40	4	10
		28.0-30.0	45	2.91	23.0	0	55	4	50
		26.0-29.0	100	2.876	25.0	2	0	24+	-----
Commercial rotary and set-kiln cement made at the same factory from the same raw-meal ^a and aërated in the same manner and time.									
6	Brand "O." Rotary process.	25-29	0	3.107	21.0	1	10	2	35
	Soundness=good. Fineness=76.3 and 93.2 per cent. Loss by ignition=1.99 per cent. Per cent of SO ₃ =0.90.	25-29	4	3.072	20.0	2	10	5	20
		26-28	7	3.056	20.0	2	30	5	30
		26-30	14	3.048	20.5	1	15	5	10
		26-30	21	3.04	20.5	0	40	2	55
		26-29	28	2.99	21.0	1	0	3	30
		28-31	60	2.91	23.0	2	35	5	10
		7	Brand "O." Set-kiln process.	25-29	0	3.10	21.0	1	0	2	40
Soundness=good. Fineness=79.2 and 95.4 per cent. Loss by ignition=1.94 per cent. Per cent of SO ₃ =0.89.	25-29		4	3.07	20.0	2	0	5	50
	26-28		7	3.055	20.0	2	20	5	30
	26-30		14	3.05	20.5	0	15	4	50
	26-30		21	3.041	21.0	0	10	3	10
	26-29		28	2.99	21.0	0	25	3	40
	28-31		60	2.90	23	2	40	5	30

^a These samples were taken at the factory at the time that the cements were being packed into barrels.

As none of the above experimental data threw any light on the variations in the set brought about by exposure to the air, we had recourse to the microscopic tests for the lime described in Part I of this paper ⁴⁹ and we thus were convinced that changes in the rate of set were brought about largely by the alterations in the condition of the free lime.

It soon became evident that the field of investigation would have to be carried beyond the study of the commercial material. Ordinarily, commercial Portland cements consist of a mixture of various kiln products the different parts of which have not seasoned in the same manner, or to the same extent. They also contain various amounts of calcium oxide, hydroxide and carbonate. Consequently, further seasoning does not produce as marked an influence on the set as when conditions are more uniformly regulated. Therefore, we again found it necessary to supplement our work on ordinary commercial cements with a study of known and selected materials which we ground, plastered and seasoned ourselves.

For this purpose we secured large quantities of fresh, non-seasoned clinkers (brands O, K, and L) from three manufacturers who were selected in order to obtain standard cements with characteristically different chemical and physical properties. The normal setting properties of these three brands of cement as previously ascertained by our routine and research work are given in Table XXIII.

⁴⁹ *Loc. cit.*

TABLE XXIII.—Characteristic setting properties of the commercial Portland cements brands O, K and L.

Brand.	Fineness.		Characteristics of chemical constituents (samples ignited).				Characteristics of the setting properties.
	200 mesh.	100 mesh.	Combined SiO ₂ .	Al ₂ O ₃ .	Fe ₂ O ₃ .	CaO.	
O	77.0	96.0	Low (20.20)	High (8.50)	Normal (2.95)	Normal (63.00)	When the cement is rather heavily plastered the initial and final sets are usually normal and stable, averaging about 1 hour 10 minutes and 2 hours 20 minutes, respectively. When lightly plastered the cement is either quick setting or very apt to become so when exposed to the atmosphere.
K	88.0	98.0	Normal (20.50)	Low (4.90)	High (4.00)	High (66.00)	The setting of this cement is very difficult to retard. Even when rather heavily plastered an extremely rapid initial and final set may be characteristic of the cement. (See Table A.) ⁵⁰
L	75.0	92.0	Normal (22.00)	Normal (6.50)	Normal (3.30)	High (66.00)	Whether heavily or lightly plastered the setting of this cement has always been found to be normal and stable. The initial set occurs in about 2 hours and 30 minutes, and the final in about 5 hours 30 minutes. Late shipments of this cement are ground much finer than formerly, but the cement still retains the above characteristics in its setting properties.

These clinkers corresponding to the cements given in Table XXIII were first crushed in a jaw crusher and then ground to the recorded fineness in an iron, air-tight ball-mill charged with sixty manganese iron balls weighing in all about 18 kilograms.

One of these manufacturers also gave us 150 kilograms of cement (classified as brand O₁ in the following work) which was ground at the factory from a 20-ton sample of hard-burned rotary clinker taken just as it had left the kiln except that it had been allowed to cool sufficiently to be sent to the crushers.

Fortunately, these samples all contained little more than a trace of sulphuric anhydride (SO₃) namely 0.10, 0.14, 0.14 and 0.15 per cent for brands O, O₁, K, and L, respectively. Therefore, they could be considered as practically free from calcium sulphate.

⁵⁰ *This Journal, Sec. A* (1910), 5, 415.

The results and conclusions derived from this study of commercial and selected material are as follows:

THE SETTING PROPERTIES OF NON-SEASONED, NON-PLASTERED PORTLAND CEMENT.

The original plastic and setting properties of these cements were essentially the same. Ground to different degrees of fineness, kneaded one and one-half or troweled five minutes, they all required a large amount of water to produce a paste of normal consistency and the neat mortar set in an abnormal, erratic manner. Also, in each case the plasticity was abnormally poor, it being extremely difficult to produce a paste which would give a penetration of 10 millimeters to the consistency needle, unless the cement was gauged so wet that water afterwards ran out from the bottom of the mold. On the other hand, if less water than that required to produce a paste of normal consistency was used, the neat mortar obtained was friable, sandy and more or less incapable of proper molding. These characteristic physical properties are shown by the figures in Table XXIV, and by the curves of the set plotted in figure 16.

TABLE XXIV.—Characteristic setting and plastic properties of normal consistency pastes made from non-plastered, non-seasoned Portland cements.

Brand.	Temperature of laboratory during gauging and setting.	Fineness through—		Per cent of water added to the cement.	Initial penetration of consistency needle in millimeters.		Initial penetration of set needle in millimeters.		Time of setting.				Soundness (5 hours steam test).
		200 mesh.	100 mesh.						Initial.		Final.		
									Hours.	Minutes.	Hours.	Minutes.	
O	27°-30°	P. ct. 89.6	F. ct. 99.0	27.5	10	40.0	2	30?	6	×	Scaly, off plate and a little soft, but not disintegrated.		
K	28°-30°	93.2	99.7	30.0	10	40.0	4	10?	8	×	Few hair-like, radial cracks, but hard and free from warping.		
L	26°, 5-30°	93.6	100.0	29.0	10	40.0	4	30	6	20	Off plate, but free from cracks or warping.		
O ₁	28°-30°	74.8	87.8	28.0	8	40.0	{ 1 45?	} 8	×	{	Soft and slightly disintegrated.		
							{ 2 50						
O ₁ ^a	28°-30°	74.8	87.8	28.0	8	40.0	{ 1 40?	} 8	×	{	Slightly disintegrated.		
							{ 3 20						
O ₁ ^b	26, °5-29°	93.8	99.7	29.0	10	40.0	{ 1 20?	} 8	×	{	Do.		
							{ 2 0						

Penetration of the set needle in millimeters.

	Time in min-utes.	Brand.					
		O. ^a	K. ^b	L. ^c	O ₁ . ^d	O ₁ . ^{e,f}	O ₁ . ^g
1	10	40	40	40	40	40	40
	20	40	40	40	40	40	40
	30	40	40	40	40	40	40
	40	40	40	40	40	40	40
	50	40	40	40	40	40	36
	60	40	40	40	40	40	39
	70	40	40	40	40	39	38
	80	40	40	40	40	35	34
	90	40	40	40	40	36	35
	100	40	40	40	40	34	34
2	110	40	40	40	34	32	28
	120	39	40	40	35	28	35
	130	38	40	40	35	28	34
	140	37	40	40	37	30	35
	150	34	40	40	37	31	32
	160	31	40	40	38	27	29
3	170	34	40	40	37	29	31
	180	31	38	40	36	28	30
	190	25	40	40	36	28	29
	200	19	36	40	34	29	30
	210	19	36	40	33	29	27
	220	6	36	40	29	28	27
4	230	4	35	40	34	27	26
	240	3	36	40	32	26	24
	250	2	35	36	31	25	23
	260	1	32	37	29	25	23
	270	1	28	35	29	25	22
	380	1	25	30	28	24	20
5	290	0.5	25	24	28	22	16
	300	0.5	23	20	28	21	19
	310	0.5	22	15	27	20	16
	320	0.5	17	7	27	18	13
	330	-----	14	1	26	8	10
	340	-----	13	1	25	7	10
6	350	-----	12	1	25	5	9
	360	-----	11	0.5	24	2	9
	370	-----	8	0.5	21	2	7
	380	-----	4	-----	5	2	7
	390	-----	3	-----	3	1	5
	400	-----	2	-----	2	1	3
7	410	-----	1	-----	2	1	3
	420	-----	0.5	-----	2	-----	3

^a Final set about 6 hours.

^b Final set about 8 hours.

^c Final set about 6.30 hours.

^d 1: 1: 1: 1: 1: 0.5.

^e Not set in 8 hours.

^f Gauge according to the United States Army cement specifications of 1902.

^g Cement O₁, reground.

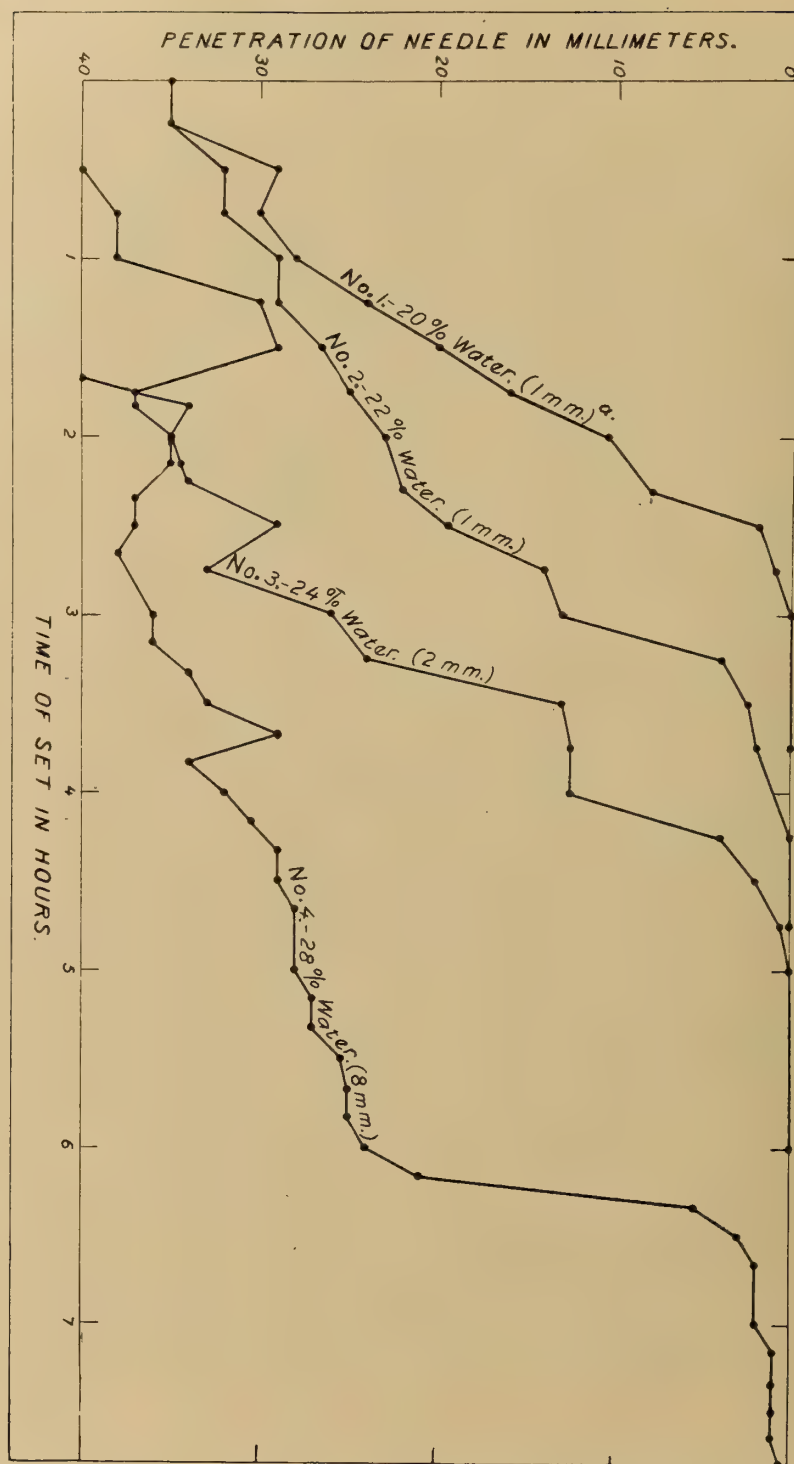


FIG. 16.

Although the normal consistency pastes of these cements set very slowly, the cements themselves are extremely quick-setting; so much so, in fact, that they set as soon as they come in contact with the water. To prove this we packed the materials in beakers and then covered them with water. When this was done they set so quickly as to be capable of supporting the set needle almost immediately. However, the degree of hardness attained by the wetter, undisturbed cement was so slight that no difficulty was experienced in troweling or kneading the set mortar thus formed into a plastic paste.

In other words, it was found that these non-plastered, non-seasoned cements set so quickly that they became regauged (tempered) by any process of manipulating them which disturbed the relative positions of their particles after water had been added. Consequently, the use of such cement in ordinary construction work would result in extremely slow setting concrete, and the setting properties shown by Table XXIV and figure 16 are those of freshly set, regauged cements. The work of S. Kasai⁵¹ illustrates this fact, since it shows that freshly set regauged Portland cements harden and soften in the erratic manner characteristic of the set curve recorded in figure 16.

Another characteristic phenomenon which occurred when these cements were gauged with water, was the almost immediate generation of a considerable quantity of heat. For instance, 100 grams of O_1 cement, added to 100 cubic centimeters of water in a 250 cubic centimeter asbestos-covered flask, gave a rise in temperature of $8^{\circ}.2$ in 4 minutes. Both the soundness and microscopic test of these cements showed that they contained free, unslaked lime. Therefore, it might be assumed that the early generation of heat was due entirely to the hydration of the free lime. However, it required about 7.0 grams of freshly ignited lime to produce the same heating effect as the 100 grams of O_1 cement. We doubted the existence of 7 per cent of uncombined calcium oxide in this material and therefore attributed part of the heat generated to the setting of the cement. Later developments proved this conclusion to be correct.

THE EFFECT OF PLASTER ON NON-SEASONED PORTLAND CEMENT.

Having ascertained these facts about the cements in their natural, non-seasoned state, we next investigated the effects produced by adding various amounts of plaster of Paris. The use of either anhydrous calcium sulphate ($CaSO_4$) or gypsum ($CaSO_4 \cdot 2H_2O$) in an equally fine state of subdivision would have produced the same results, provided that weight for weight correspondingly greater or smaller quantities had been employed according to the amount of water which they contained.

Generally speaking, the sulphate of calcium when added in quantities up to 2 to 3 per cent retards the natural set of Portland cement. Used in larger

⁵¹ Das Abbinden der Portlandzemente. Onoda, Japan (1908).

amounts its retarding influence is less. Consequently, it was usually found unnecessary to carry the investigation beyond 3 per cent.

The results obtained by adding small amounts of plaster in increasing quantities to the non-seasoned material are shown by figure 17.

As the amount of plaster used was increased step by step in each cement, the initial set took place earlier, then later, and finally again earlier. In each instance, also, the amount of water required to produce a paste of normal consistency at first decreased decidedly, and then later slightly increased. However, as is readily apparent from figure 18, the curves of which are plotted from the data recorded in figure 17, the same quantity of plaster did not effect the set and plasticity of the different cements to the same extent.

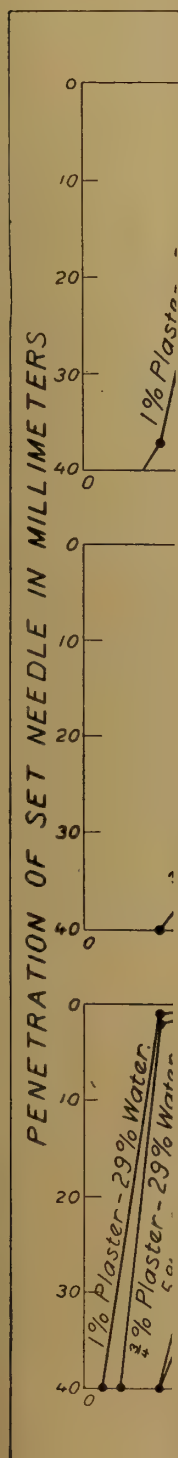
All of these cements contained free, sintered and non-sintered lime. Table XXV shows that the presence of small amounts of plaster of Paris such as we used has no appreciable effect upon the slaking of ignited lime.

TABLE XXV.^a—*The effect of plaster of Paris on the heat generated by the slaking of freshly ignited lime in an excess of water.*

Experiment No.	Contents of the calorimeter in grams.	Temperature of the calorimeter and water.	Temperature of the calorimeter and its contents after the solids had been added, the laboratory temperature remaining between 26°.5 and 27°.0.				Total rise in temperature.
			After 1 minute.	After 2 minutes.	After 3 minutes.	After 4 minutes.	
1	{ 75 water..... 20 plaster..... }	26.0	26.0	26.0	26.2	26.4	0.4
2	{ 75 water..... 10 lime..... }	26.0	53.0	51.0	49.5	48.5	27.0
3	{ 75 water..... 10 lime..... 1 plaster..... }	26.0	53.0	51.0	49.5	48.5	27.0
4	{ 75 water..... 10 lime..... 2 plaster..... }	26.5	53.0	51.0	49.5	48.5	26.5
5	{ 75 water..... 10 lime..... 4 plaster..... }	27.0	54.0	51.0	49.0	48.0	27.0
6	{ 75 water..... 10 lime..... 8 plaster..... }	27.0	53.0	51.0	49.5	48.5	26.0

^a The calorimeter used consisted of an asbestos-covered 250 cubic centimeter Erlenmeyer flask, fitted with a rubber stopper containing the thermometer. Although rather crude it is sufficiently accurate.

Therefore, in the presence of an excess of water, other conditions remaining the same, the heat generated by the slaking of the lime in a given cement is independent of the amount of plaster which the cement



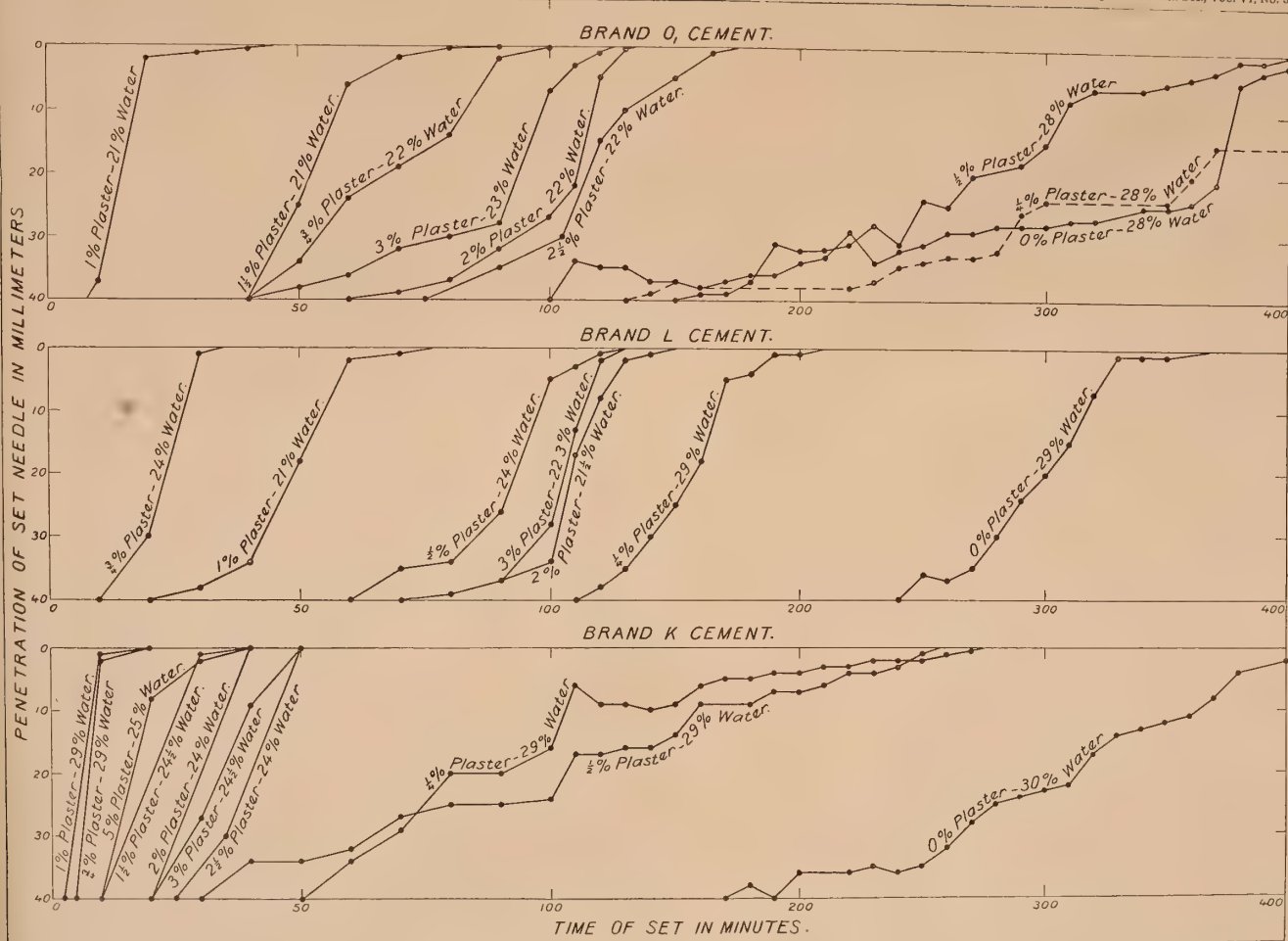


FIG. 17.

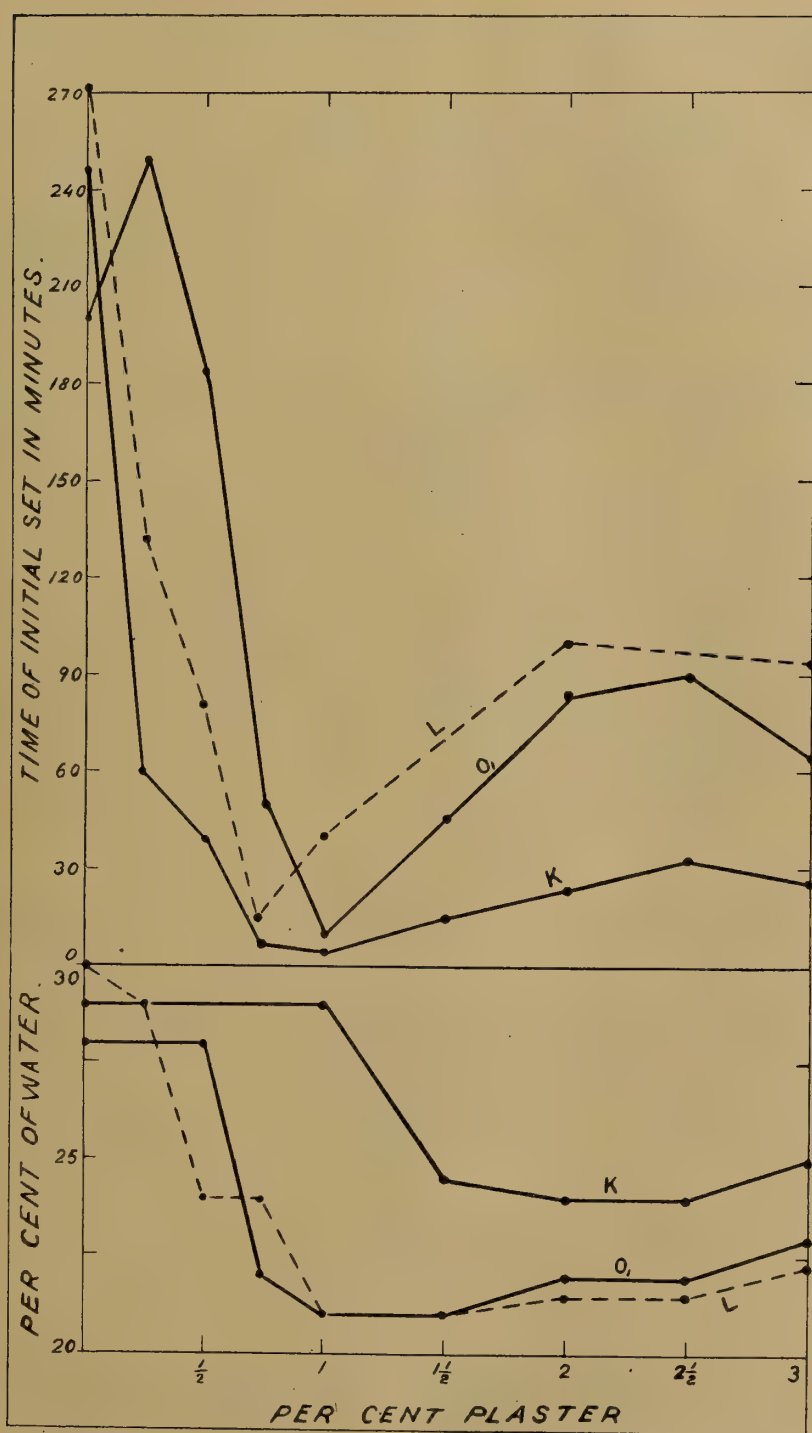


FIG. 18.

contains, and the influence of this factor remains practically a constant for each cement. With this fact thoroughly in mind the effects of different amounts of plaster upon the plastic and setting properties of non-seasoned cements may readily be explained.

Thus, from figure 17 and calorimetric tests with brand L cement we obtained the figures in Table XXVI.

TABLE XXVI.—*The effects of various amounts of plaster on the heat generated, and the plastic and setting properties of non-seasoned, brand L cement.*

Contents of the calorimeter, in grams.	Total rise in temperature in 4 minutes.	Per cent of water required to produce a paste of normal consistency.	Time of initial set in minutes.	Remarks.
	°C.			
75 water----- 50 cement-----	4.1	29.0	270	A regauged cement paste.
75 water----- 50 cement + 0.5 per cent of plaster.				
75 water----- 50 cement + 1.0 per cent of plaster.	2.6	24.0	80	{ A partially regauged cement paste.
75 water----- 50 cement + 2.0 per cent of plaster.				
75 water----- 50 cement + 1.0 per cent of plaster.	1.8	21.0	40	A normal cement paste.
75 water----- 50 cement + 2.0 per cent of plaster.				
75 water----- 50 cement + 2.0 per cent of plaster.	1.8	21.5	100	Do.

From these figures it is seen that the constant rise in temperature due to the heat generated by the slaking of the lime in this cement is $1^{\circ}.8$. Any excess above this must be due to the chemical activity of the compounds which cause the cement to set. When no plaster had been added to the cement, the temperature of the calorimeter rose $4^{\circ}.1$, or $2^{\circ}.3$ in excess of the lime factor. As already stated, the normal consistency-paste made from this cement was that of a regauged, freshly set cement, which therefore required a large amount of water and set very slowly.

The use of 1 per cent of plaster reduced the rise in temperature of the calorimeter to the constant lime factor ($1^{\circ}.8$). It also retarded the rate of reaction of the setting compounds until long after the cement had been molded ⁵² (40 minutes). Consequently this cement was not

⁵² In this calorimetric work we only took the early rise in temperature, provided it remained constant at the end of 4 minutes. The reason for so doing is that according to the American Society specifications which were used it requires about 4 minutes to knead and mold and to test the consistency of the cement.

regauged. Therefore it also required only a minimum amount (21 per cent) of water.

The use of 0.5 per cent of plaster was not sufficient entirely to retard the rate of reaction of all the setting compounds to the normal but it did so to a certain extent, because the temperature of the calorimeter only rose $0^{\circ}.8$ above that of the lime factor. This normal consistency-paste may therefore be considered as a partially regauged cement, a conclusion which is corroborated by the corresponding requirement of water (24 per cent) and time of initial set (80 minutes). More than 1 per cent of plaster only retarded the set, until finally from 2 to 3 per cent produced a maximum result. Beyond this amount the natural tendency of plaster of Paris to set very quickly manifested itself in the combined results obtained, and the time of initial set again approached a minimum.

The general character of the plastic and set curves derived from brand O_1 and K cements can be accounted for by similar analytical reasoning, the only difference being that cement K required 1.5 per cent of plaster totally to retard the rate of its setting sufficiently to permit the molding of a normal consistency-paste.

Table XXVII gives a comparison of the quantitative effects of the same amount of plaster on the different cements. It shows that the setting properties of the normal consistency-pastes made from cement L are more readily retarded than those from cement O_1 . At the same time it is seen that it is almost impossible to retard the set of cement K sufficiently to pass the requirements of our standard specifications.

TABLE XXVII.—*The quantitative effects of plaster upon the initial set of non-seasoned L, O_1 and K cements.*

Brand.	The per cent of plaster required—			The maximum retardation of the time of initial set, in minutes.
	To prevent regauging.	To retard the initial set sufficiently to pass the requirements of the A. S. T. M. specifications.	To produce a maximum retardation of the initial set.	
L	1.0	1.0	2.0	100
O_1	1.0	1.5	2.5	85
K	1.5	2.5	2.5	32

THE EFFECT OF SEASONING ON NON-PLASTERED PORTLAND CEMENTS.

We next studied the changes in the plastic and setting properties of non-plastered Portland cements brought about by various methods of seasoning. The condition of the free lime was noted in each test.

The result of thoroughly aërating cement O_1 in an open shallow pan, are given in Tables XXVIII and XXIX.

TABLE XXVIII.—*The effects of aëration on non-plastered, non-seasoned, O_1 cement.*

Time of exposure in days.	Specific gravity (dried at 110°).	Per cent increase in volume per unit weight.	Condition of the free lime (microscopic test).	Calorimeter test (rise in temperature in 4 minutes).	Per cent of water required to produce a paste of normal consistency.	Time of initial set in minutes.	Remarks.
0	3.19	0.0	Mostly calcium oxide (CaO).	8° 2 (constant lime factor = 2° 0).	28.0	200	A freshly set regauged paste.
14	3.10	2.9	No CaO. Slaked lime $[Ca(OH)_2]$ in considerable quantity.	0° 2	22.0	10	A normal paste.
40	3.07	3.9	No CaO. A very little slaked lime.	0° 0	23.0	5	Do.
90	3.04	4.9	No CaO. No $Ca(OH)_2$. Available free lime all converted into calcium carbonate.	0° 0	30.0	15	Do.

TABLE XXIX.—*The effects of plaster on O_1 cement before and after its free lime had become thoroughly hydrated.*

Cement.	Per cent of plaster added.	Calorimeter test (rise in temperature in 4 minutes).	Per cent of water required to produce a paste of normal consistency. ^a	Time of initial set in minutes.	Remarks.
O_1 -----	0.0	8° 2	28.0	Instantaneous (200 regauged).	A freshly set regauged paste.
O_1 aërated 14 days -----	0.0	0° 2	22.0	5	A normal paste.
O_1 -----	0.5	5° 0	28.0	Instantaneous (185 regauged).	A partially regauged paste.
O_1 aërated 14 days -----	0.5	0° 0	21.0	185	A normal paste.
O_1 -----	1.0	2° 0	21.0	10	Do.
O_1 aërated 14 days -----	1.0	0° 0	21.5	165	Do.
O_1 -----	1.5	2° 0	21.0	45	Do.

^a The figures in this column are computed by weight. The aërated cement has 2.9 per cent more absolute volume per unit weight than O_1 non-seasoned. Therefore the aërated cement requires less water by volume.

Tables XXVIII and XXIX show that as soon as the free lime in this cement had become thoroughly slaked, less water and less plaster

were required to produce a normal paste of standard consistency and set. Similar treatment affected the other three cements in the same general manner, the difference being that the set of brand L could be retarded the most and that of K the least.

Similar results were also secured by any process of seasoning either the ground cement or clinker, provided the process slaked the free lime and at the same time did not permit the cement to set or cake. (See Table XXX and figure 19.) The efficiency of different methods of seasoning depended entirely upon the relative amounts of slaked lime produced and maintained, the conversion of calcium hydrate into calcium carbonate acting so as to decrease the plasticity and the retarding influence of the sulphate.

We have already discussed the most and least efficient methods of converting the uncombined calcium oxide in Portland cement into its hydrate, in Parts I and II of this paper⁵³ and therefore no further comment on this phase of the problem is necessary.

THE EFFECTS PRODUCED BY THE SEASONING OF PLASTERED CEMENTS.

No radical difference was manifest if plaster was added before the cement had seasoned. It has already been shown that the presence of calcium sulphate exerts no appreciable influence upon the slaking of the lime, and the results so far obtained all indicate that the substitution of calcium hydroxide for calcium oxide in Portland cement tends to decrease the rate of the set, and to add somewhat to the plasticity.

The heat generated by slaking ignited lime in the presence of an excess of water is very considerable.⁵⁴ Generally speaking, Portland cements set more quickly at a high than at a low temperature other conditions remaining the same. Consequently, it seems reasonable to assume that if free calcium oxide is present when water is added, the heat of hydration throughout the mass of the cement paste will tend to increase the normal rate of the set. The extent to which the same quantities of free lime may effect this activity in different cements is not constant, because all hydraulic setting compounds are not affected to the same extent by heat. Results obtained with the three brands of material under investigation showed this very clearly, brand L being the least affected and brand K the most.

However, in these experiments with the samples after aëration, it is reasonable to believe that the compounds which react with water and cause the cements to set might also have been affected by the moisture and carbon dioxide which altered the condition of the free lime so as to eliminate its heating effect. The results indicate that such was not the case, or rather that if this action took place it did so only to a very

⁵³ *This Journal*, Sec. A (1910), 5, 367 and 415.

⁵⁴ 269 calories.

slight extent. In the first place prolonged, thorough aëration failed to eliminate the power of the commercial or selected material to set, unless the time of exposure was carried far beyond that required to convert the hydrated lime into calcium carbonate. For instance, the non-plastered cement described in Table XXVIII sets in fifteen minutes after being thoroughly aërated for three months and the commercial plastered cements (Table XXII) all retain a normal initial set after similar treatment. Then too, it was found that when the seasoned cements were ignited at a low red heat, their original physical properties in this respect again returned. Had the compounds which cause the cements to set decomposed to any considerable extent it would have required incipient fusion to restore their original setting properties.

Another fact which tends to support the same conclusion is demonstrated by the results obtained from the following experiment.

Two samples, each consisting of 40 kilograms of the non-seasoned, thoroughly mixed, hard-burned rotary clinker K were dumped into coverless wooden boxes. One of these was stored in the laboratory. The other was weathered outside where the clinker was frequently wetted, it being the time of the local rainy season. At the end of the three months these samples, together with the non-seasoned clinker which had been preserved in a sealed glass jar, were each thoroughly dried and ground in the same ball mill to pass a 100-mesh sieve and to as nearly the same degree of fineness as possible. The results of the tests are shown by Table XXX and figure 19.

TABLE XXX.—*Physical and chemical properties of seasoned and non-seasoned, hard-burned, rotary clinker, brand K.*

Character of test.	Loss by ignition.	Specific gravity (dried at 110°).	Free lime.	Calorimeter test (comparative constant lime factor or the rise in temperature due to the slaking of free lime).	Microscopic test (relative quantities of slaked lime present in the ground cement).
	<i>Per ct.</i>			<i>°C.</i>	
Clinker stored in a airtight receptacle.	0.62	3.15	Considerable CaO. Very little Ca (OH) ₂ .	3.0	Very little.
Clinker aërated 3 months in an open wooden box stored in the laboratory.	1.78	3.10	Very little CaO. Considerable Ca(OH) ₂ .	1.0	Considerable.
Clinker stored in an open wooden box and weathered 3 months outside during the rainy season.	2.57	3.07	No CaO positively identified. Considerable Ca(OH) ₂ .	0.7	Considerably more than in the preceding sample.

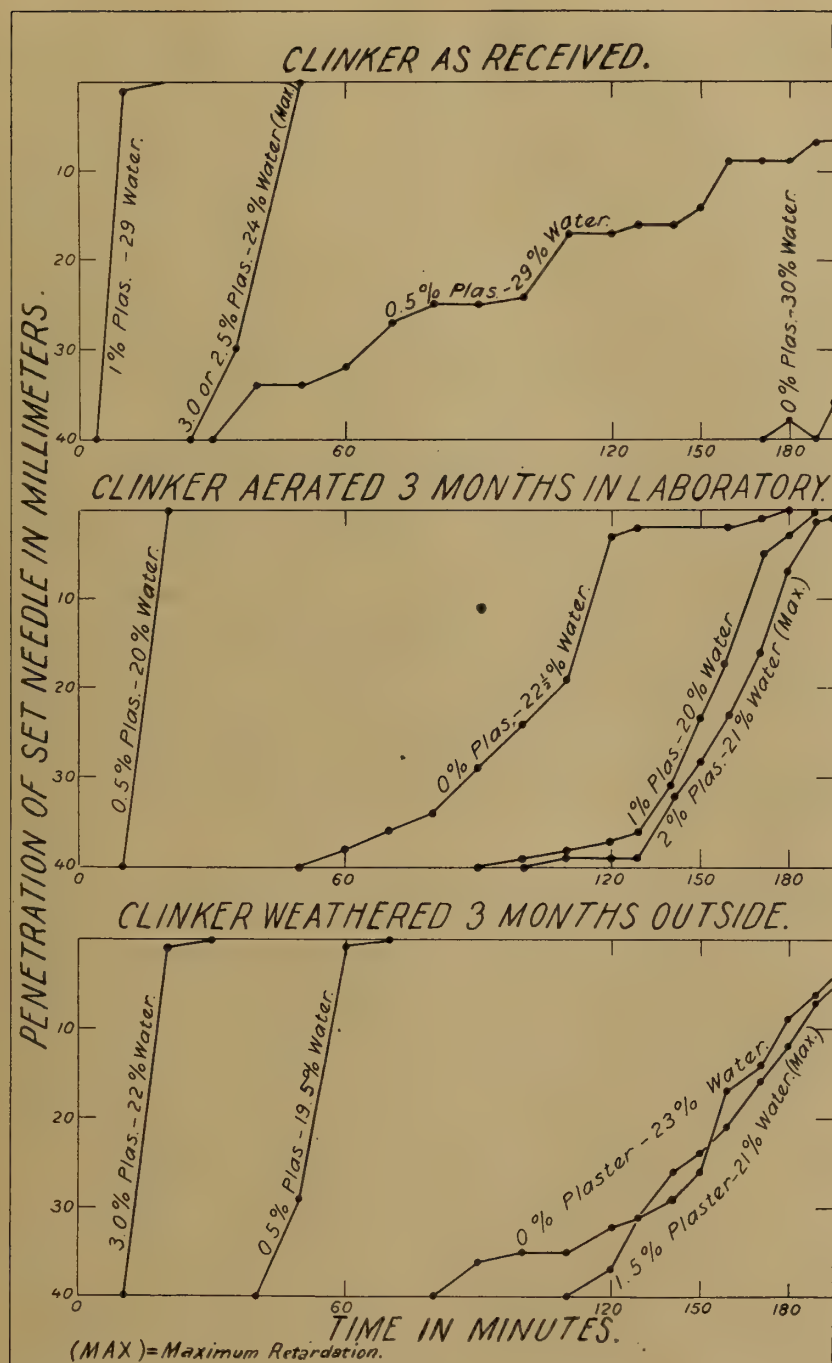


FIG. 19.

It was demonstrated in Parts I and II of this paper that water, or water and carbon dioxide, have no appreciable influence on perfectly sintered or thoroughly fused Portland cement in the clinker form, and that it is only the free lime in hard-burned clinker which is effected by these elements. Consequently, we believe that the hydraulic compounds in this hard-burned clinker, brand K, which gave to the powdered material its power of setting, underwent very little decomposition during the processes of seasoning employed. However, after these samples had been dried and ground to the same degree of fineness, the cement produced from the seasoned clinkers was decidedly different from the non-seasoned product. The changes induced by this method of seasoning, in general character, were essentially the same as those obtained by aërating the clinker after it had been pulverized. Therefore, we attribute the changes to the altered condition of the lime. The data obtained from this experiment tend especially to confirm this conclusion, since as has already been emphasized in this paper, the Portland cement clinker seasoned more efficiently when frequently wetted than when merely exposed to the atmosphere under cover.

The changes in plasticity can also be accounted for by alterations in the condition of the free lime. Aside from the fact that the presence of calcium oxide tends to promote regauging to a greater or lesser extent, the somewhat increased plasticity which even normal pastes show after the free calcium oxide has been substituted by the hydrate, can be accounted for by the now well-known fact that ignited lime may hydrate to a crystalline as well as to an amorphous form.⁵⁵

Bechtenkirker⁵⁶ and others have shown that slow hydration at a low temperature tends to produce the amorphous form, and *vice versa*; and that the crystalline one is the least plastic. Therefore, when the free lime in Portland cement remains unslaked until the cement is gauged, the heat generated throughout the mass because of the immediate slaking of the free lime may be sufficient to cause some of the oxide to hydrate at so high a temperature that the crystalline product is formed. On the other hand, when the hydration of the free lime is slow, as is the case when the cement is subjected to the ordinary processes of seasoning, the hydrate formed may be entirely amorphous. Then too, in the latter case, the water required to slake the free lime has already been added, so that none of the gauging water is required for this purpose.

Calcium hydroxide readily absorbs carbon dioxide so that if the seasoning is accomplished by exposing the cement to the air more or less calcium carbonate is formed. Calcium carbonate is a crystalline substance. In Portland cement it is inert and lowers the specific gravity. Therefore, the substitution of calcium carbonate for the slaked lime in Portland

⁵⁵ See figure 4, Part I, p. 377.

⁵⁶ *Rock. Prod.* (1907), 7, 23.

cement tends to reduce the plasticity. Otherwise, the differences between the plasticity of non-seasoned and aerated cement pastes would be greater than those shown by the preceding work. For the same reason, the setting properties would have been affected to a greater extent.

It also is known that the presence of lime in a state in which it is immediately available as a soluble hydroxide, largely increases the efficiency of calcium sulphate as a retarder. Therefore, as explained by Candlot, the same substitution of calcium carbonate for calcium hydrate tends again to increase the rate of set in plastered Portland cements.

We have endeavored to show that two successive changes occur in the condition of the free lime during the ordinary process of seasoning Portland cement, the first of which tends to decrease, and the second to increase, the normal rate of the set. In order to demonstrate the extent to which these facts affect the problem under discussion, it is necessary to take some additional facts into consideration.

We have stated that the compounds which cause cements to set are but slightly altered by exposure to the atmosphere. This is true for the time of exposure necessary to convert the available calcium oxide into hydroxide. However, when Portland cements are undergoing thorough aëration, the rate of set gradually decreases after no more available slaked lime is present. Ultimately, after prolonged exposure, the cement may finally become inert. In this respect coarsely ground, hard-burned cements retain a normal set longer than finely ground material.

Figure 20 shows the results obtained by thoroughly aërating a coarse and a finely ground cement for 9 months. (See Table XXII, samples 1 and 2.)

The coarsely ground cement gained its initial set in 7 hours while the finely ground cement which had been seasoned in the same manner and during the same time gained its initial set only after 23 days.

Plate VI shows the same phenomenon in a specially interesting manner because it illustrates a cause of unsoundness heretofore not mentioned in the literature on the subject.

Unsoundness in this instance was due to the fact that the finest particles in the cement had become very inert, whereas the coarser ones still retained considerable activity. When the pat was molded, the light, fine particles "floated" to the upper surface and formed an outer covering about 1.5 millimeters thick which failed to harden sufficiently to prevent the strains developed in the boiling test from "blowing" and cracking it from the hardened cement underneath.

Three changes in the rate of the set have been accounted for by the tendency of water and carbon dioxide gradually to render the cement itself inert. However, the work on commercial cements showed that in some instances (see Table XXII, sample number 4) four changes take place. When these occur the set is first accelerated, then retarded, again accelerated and finally again retarded. The first set obtained is that of a partially regauged cement paste. When a cement sets so quickly that

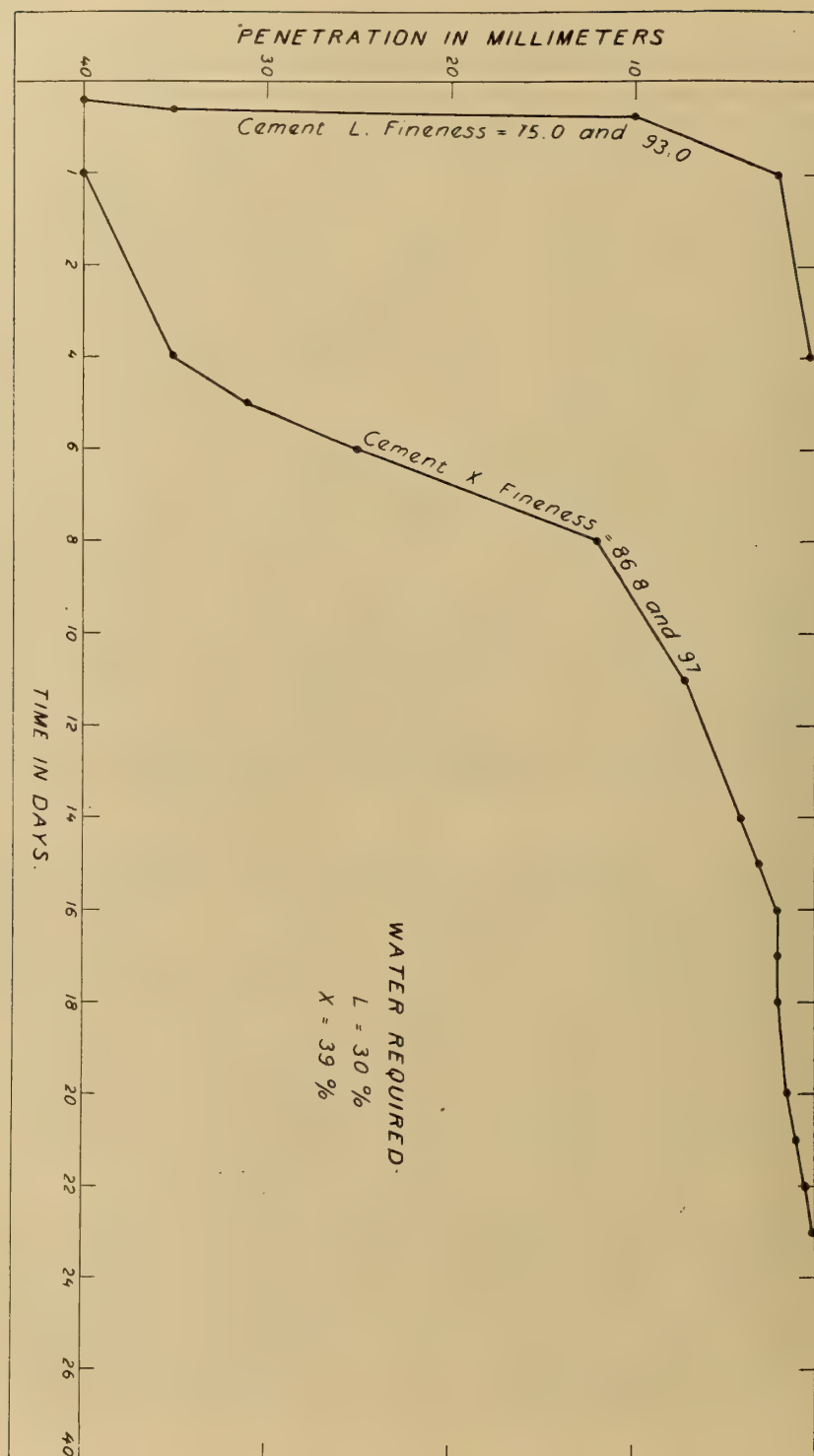


FIG. 20.

it is entirely regauged during the process of mixing, the heat generated is so great that the tester becomes aware of the rise in the temperature of the paste even though his hands are protected by rubber gloves. The amount of water required and the stiffness of the paste are also abnormal. Consequently, it seldom occurs that a cement is entirely regauged without the fact being noted. On the other hand, when the cement is such that regauging occurs only to a small extent, this fact is not made apparent because such cements may heat but slightly and require less than 24 per cent of water, whereas some cement pastes which set normally require more than this amount and also heat considerably during the process of mixing. Therefore, although the contents of this paper have made it possible to identify partial regauging, cement testers seldom notice or record the phenomenon when it only occurs to a slight extent. In fact, no attention has heretofore been given to the subject. As a result, the setting properties of many cements are reported upon favorably, whereas if the true facts were known, the report would be very unfavorable.

THE CONTROL OF THE SETTING PROPERTIES OF PORTLAND CEMENT.

The primary object of the preceding work was to find a means whereby the changes in the compounds in Portland cement might be so controlled that serious alterations in the rate of setting could not occur.

Fortunately, it is not essential that the rate of setting remain absolutely fixed and unchanged in order successfully to solve this problem. In ordinary construction work, changes in the set are not of serious importance, unless the cement becomes abnormally quick or slow setting. When an abnormally quick setting cement is desired and specified for tidal, or other special purposes, it is only essential that the cement remain abnormally quick setting. Therefore, the set may change, but in so doing it must constantly remain within specified, desired limits. An analysis of the cement before it is packed, such as is outlined by our treatment of the selected material, will not only inform the manufacturer if the product of his kiln is capable of being put under practical control, but also fix the minimum amount of retarder required to do so.

Cement O₁ can be taken as a specific example. We found that when the free lime was all present as calcium oxide, it required 1.0 per cent of plaster to prevent regauging and 1.5 per cent to produce a normal initial set (not less than 30 minutes). After the cement had seasoned until the microscopic test showed only slaked lime, it required but 0.5 per cent of plaster to prevent regauging and produce a normal set. (See Table XXIX.)

Therefore, it would be predicted of this cement that if less than 1.0 per cent of plaster is added it could season so that four radical changes would occur in its setting properties, and that the set at times would become abnormally quick. Two changes could be brought about by seasoning the cement so that the free lime would gradually slake. The first effect of this would be to eliminate the regauging. As soon as this was accomplished an abnormally quick-setting paste

would result. The further hydration of the lime would tend to retard the set until finally, as shown by the figures in Table XXIX; its rate would become normal. A third change could be brought about by converting the slaked lime into calcium carbonate, in which event the mixture would again become quick setting and remain so until the cement itself was allowed to become so inert as to set very slowly.

It would also be predicted of this cement that if more than 1.0 per cent of plaster were to be added, seasoning could only induce three radical changes in its setting properties. One change only could be brought about by the slaking of the free lime, as this would result in increasing the efficiency of the plaster alone, thereby retarding the set. The data recorded in Table XXIX and figure 18 also indicate that if as much as 1.5 per cent of plaster is present, the slaking of the lime would not cause the set of the cement to change beyond the normal, but that if less than this amount is added, the set would change from abnormally quick to normal. Two other changes could be induced to take place; the first by converting the slaked lime into calcium carbonate, and the second by then aerating the mixture until the cement itself became sufficiently inert so that the rate of set would again become slow. Accordingly, the changes in set which in reality took place when O_1 cement was first plastered and then subjected to thorough aëration were as shown by Table XXXI.

Conditions of the experiment recorded in Table XXXI.—A sample of 30 kilograms of O_1 cement was divided into two equal parts to one of which 0.5 and to the other 1.5 per cent of plaster were added. These two mixtures were then thoroughly aërated side by side in shallow pans and from time to time subjected to the tests as given in the table:

TABLE XXXI.—Changes in the setting properties of plastered O_1 cement.

(Temperature of the laboratory during the mixing and setting = 27° to 29°.)

Time aërat- ed in days.	O, cement+0.5 per cent of plaster.				O, cement+1.5 per cent of plaster.			
	Specific grav- ity.	Free lime (microscopic test).	Quantity of water required to pro- duce a normal consist- ency paste.	Time of initial set in min- utes.	Specific grav- ity.	Free lime (microscopic test.)	Quantity of water required to pro- duce a normal consist- ency paste.	Time of initial set in min- utes.
			<i>Per cent.</i>				<i>Per cent.</i>	
0	3.184	Mostly CaO. A little Ca (OH) ₂ .	28.0	*185	3.180	Mostly CaO. A little Ca(OH) ₂ .	21.0	45
3	3.153	CaO, Ca(OH) ₂ ----	18.5	15	3.153	CaO, Ca(OH) ₂ ----	20.0	120
7	3.130	Ca(OH) ₂ -----	19.0	115	3.122	Ca(OH) ₂ -----	19.5	165
13	3.107	A little Ca(OH) ₂ -	20.5	110	3.114	A little Ca(OH) ₂ -	20.0	150
18	3.100	No Ca(OH) ₂ -----	20.5	35	3.107	No Ca(OH) ₂ -----	20.5	140
28	3.063	-----do-----	21.5	5	3.077	-----do-----	21.0	90
37	3.050	-----do-----	22.0	5	3.063	-----do-----	21.5	30
48	-----	-----do-----	-----	-----	3.03	-----do-----	22.0	15
90	2.920	-----do-----	25.5	100	2.928	-----do-----	25.5	170

* Partially regauged.

Figure 21 diagrammatically shows the changes in set and plasticity which took place as the specific gravity of the cement gradually decreased.

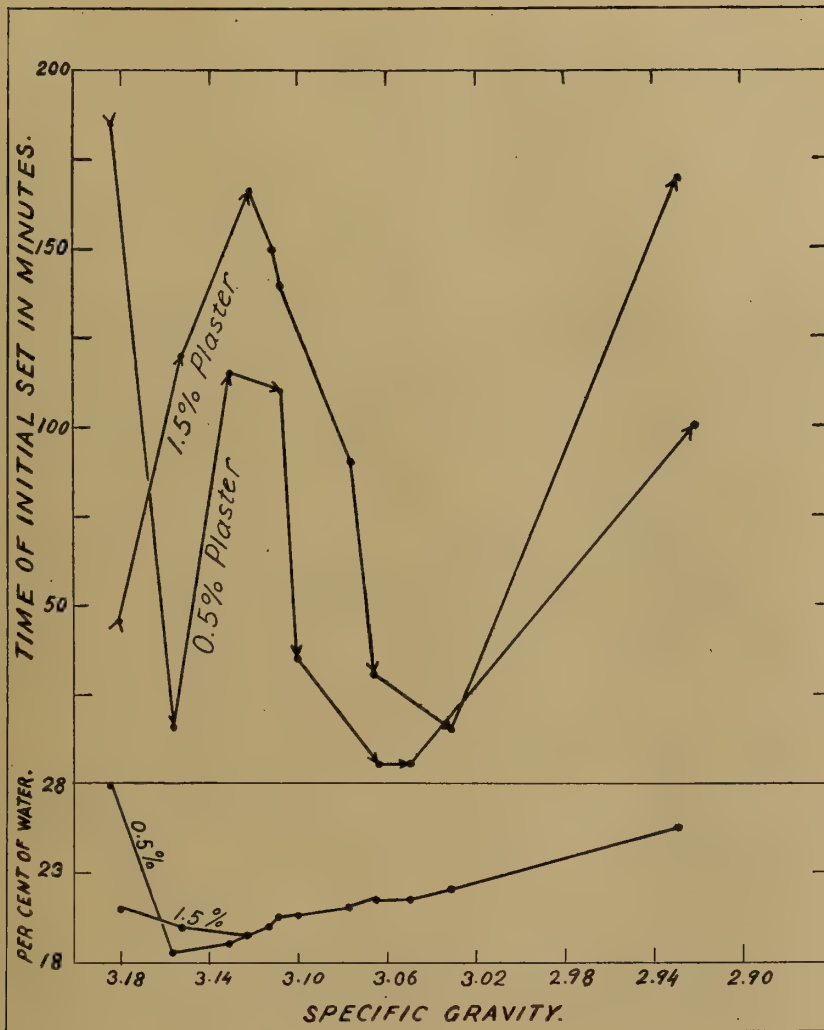


FIG. 21.

The figures recorded in Table XXXI prove that the behavior of these mixtures when subjected to thorough aëration was exactly as had been anticipated. They show conclusively that the manufacturer before packing his cement can readily ascertain the nature and extent of changes in set which future seasoning may induce.

However, air only penetrates slightly beyond the exposed surfaces of packed cement, water absorbed from the atmosphere readily enters farther. The free lime will gradually unite with the water which may be present as moisture in Portland cement, if no other source of water is available. Consequently, it is the effect of the hydration of the lime, and not its conversion into calcium carbonate to which the manufacturer

must give special consideration; and therefore, if he packs his cement in sound, paper-lined barrels or in air-tight, water-proof bags, he need only concern himself with the changes in set which are brought about by the conversion of free lime into its hydrate. The free lime in Portland cement packed in this manner and properly stored can not possibly become converted into calcium carbonate except to a slight extent.⁵⁷

For example, these same mixtures of O_1 cement were also stored, packed to a depth of 12 centimeters in open beakers. The only changes in set which took place were those caused by the hydration of the free lime: i. e., the mixture containing 0.5 per cent of plaster, after first becoming quick setting, became and remained slow setting; while the other mixture remained slow setting at all times. The microscopic test showed that only the cement on and near the upper surfaces became thoroughly aerated and that the free lime in at least four-fifths of the cement did not become converted into calcium carbonate. Consequently, only the effects caused by the hydration of the free lime manifested themselves in the combined results obtained. (See Table XX.)

The conversion of slaked lime into calcium carbonate is very apt to occur to a considerable extent if the cement is packed in ordinary paper or cloth bags, or if the samples taken from the commercial packages are not properly protected from the atmosphere. However, as this matter has already thoroughly been discussed in one of our previous publications⁵⁸ it only is necessary further to state that proper packing is essential not only for the control of the set but also for the preservation of the strength of good Portland cement.

It seems that the setting properties of O_1 cement are truly characteristic of the general nature of the commercial product which it represents. (See Table XXIII.)

Experiments with the abnormally quick-setting cements received from this manufacturer have resulted in the following observations:

1. The set of the cements could always be retarded to normal requirements by the addition of from 0.5 to 1.0 per cent of plaster.
2. When aerated, the most lightly plastered cements remained quick setting.
3. When aerated, the most heavily plastered cements soon became normally slow setting.

It was claimed (and a later inspection of the records at the factory upheld this) that certain of these quick-setting cements had been carefully tested before they left the mill and that they then were slow setting. At that time we were unable to account for the change in set which had evidently occurred after the cements were packed. However, it now appears that the results obtained at the factory were those produced by partially regauged cement pastes.

The physical testing at cement plants is usually intrusted to employees who although conscientious and faithful, do the work in a purely

⁵⁷ See Tables IX and X, Part II of this paper.

⁵⁸ *This Journal*, Sec. A (1908), 3, 137.

mechanical way and know little of the scientific technical considerations involved. One of us had occasion to work with the routine cement tester of this large manufacturing plant. Together we took the setting properties of a number of samples all of which, apparently, gave satisfactory results. However, by means of the calorimeter test, it was found that one produced a partially regauged cement paste. This cement was exposed to the atmosphere for a few hours and again tested. A normal but extremely quick-setting paste resulted.

Later, the arrival of another shipment of abnormally quick-setting cement from this same manufacturer gave us an opportunity to test our conclusions regarding the regauging of the cement at the factory. Accordingly, we subjected this material to a careful examination the essential results of which are recorded in Table XXXII:

TABLE XXXII.—*Setting properties of brand O cement tested for request No. 85725.*

Quick setting cement (fineness=76.2 and 96.0; per cent of $\text{SO}_3=0.89$).	Temperature of laboratory during the mixing and setting.	Specific gravity.	Quantity of water required to produce a paste of normal consistency.	Time of initial set in minutes.
	°C.		Per cent.	
As received	26-27	3.12	23	20
As received but aerated 4 hours.....	26-27	3.11	22	10
As received but aerated 21 hours.....	26-27	3.09	20	70
As received but aerated 27 hours.....	27-28	3.08	20.5	90
As received but aerated 40 hours.....	27-28	3.07	21.0	60
As received + 0.5 per cent of plaster.....	28-29	×	22	60

From these figures it is evident that the cement as received had not seasoned sufficiently entirely to eliminate regauging during the process of mixing, and furthermore, that a slow-setting paste could have been obtained at the factory only because less calcium had become slaked and consequently regauging had occurred to some extent.

Cement L also proved truly characteristic of the general nature of the commercial product which it represents.

We have never encountered a quick-setting sample of brand L cement even when as little as 0.46 of sulphuric anhydride (SO_3) was present. Formerly the manufacturer ground this cement so coarsely that this was thought to account for its slow set. However, during the last year the material from the same mill has been much more finely ground and although the chemical composition and specific gravity have remained practically unchanged the cement as heretofore continued to set very slowly. In fact we reground some to an extremely fine

powder and found that it still retained a rather slow normal set. These facts are shown more specifically by the figures given in Table XXXIII:

TABLE XXXIII.—*The effect of fineness of grinding upon brand L cement.*

	Fineness.		Specific grav-ity.	Initial set.		Final set.	
	200-mesh.	100-mesh.		Hours.	Min-utes.	Hours.	Min-utes.
Average results of cement L tested per request No. 74109.....	74.7	95.6	3.10	2	18	5	16
Average results of cement L tested per request No. 74272.....	83.7	97.3	3.10	1	57	4	20
Mixture of cement L as received	73.8	94.2	3.10	2	25	5	20
Same as above reground	89.5	100.0	3.09	1	30	4	00

Although the data in Table XXVII and figure 17 show that the effects of plaster on the non-seasoned cement L were in general similar to those on cement O₁, it is also evident that L produced a cement which comparatively was slower setting than O₁ and that it required less plaster (1.0 per cent) to prevent regauging and to retard the set to normal requirements.

Accordingly, it was found that the addition of 1.0 per cent of plaster to cement L was sufficient not only to insure the practical control of its setting properties, but also to obtain a slower setting cement than a similar mixture with O₁. Therefore, the characteristic slow set of the commercial product which L represents seems to have been duly accounted for.

Cement K introduces more complicated considerations, because the practical control of its set necessitates a preliminary process of seasoning.

Formerly, all Portland cement clinkers had to be seasoned, as otherwise the cement would be unsound. Now, the best rotary practice yields a clinker which is sound when fresh. Therefore, it being very often desirable to use the material as soon as possible, the packing of fresh cements is of more and more frequent occurrence. Samples O₁ and L are characteristic of cements the setting properties of which can be put under control even though the clinker is plastered, ground and packed without previously having been seasoned.

However, it sometimes happens that the nature of a cement is such that it must be seasoned before the plaster is added, or otherwise the set can not be controlled. This was found to be especially true of cements which contain a considerable percentage of anhydrous free lime, or whose setting properties are greatly influenced by thermal conditions.

Table XXVII and figure 17 show that the addition of 2.5 per cent of plaster to the non-seasoned cement made from K produced a maximum retardation of the initial set of 32 minutes. On the other hand, figure 19 shows that it was possible so to season the K clinker, that when ground, the addition of 1.5 per cent of plaster gave a maximum retardation of the initial set of 135 minutes. Therefore, we thought that 2.5 per cent of plaster would keep this cement normally slow setting under all conditions of ordinary storage. Accordingly, we aerated a

2.5 per cent mixture in a shallow pan until the microscopic test detected only slaked lime. The results obtained are given in Table XXXIV:

TABLE XXXIV.—*The effects of aëration on the setting properties of non-seasoned cement K + 2.5 per cent of plaster.*

Time aërated in days.	Specific gravity.	Water required in per cent.	Temperature of laboratory during the mixing and setting.	Time of setting in minutes.	
				Initial.	Final.
0	3.11	24.0	27° -28°	30	50
1	3.10	21.0	27°.5-29°	35	150
2	3.09	21.0	27° -30°	40	240
5	3.06	24.0	27° -29°	35	250
5	3.06	24.0	*31° -31°.5	10	150

* Obviously the activity of the setting compounds in cement K is greatly influenced by thermal conditions. On the other hand the set of cement L remained practically constant for temperatures varying from 26° to 32°.

The figures in Table XXXIV show that this mixture remained too quick setting and too susceptible to changes in heat to guarantee a normal initial set under all ordinary conditions of storage and use. However, this same cement mixed with only 2.0 per cent of plaster and aërated in the same manner soon became and remained slow setting.

The cause of this apparent discrepancy is explained by the curves in figure 22. (See also figure 19.)

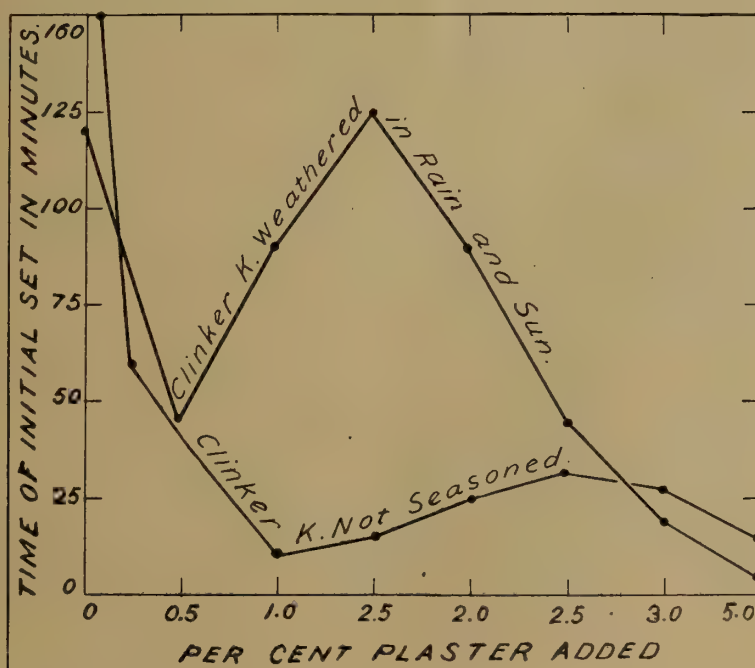


FIG. 22.

According to this diagram, the slaking of the free lime in a 2.5 per cent mixture would only be capable of retarding the time of initial set from one of 32 to one of 45 minutes, whereas the same action in a 2.0 per cent mixture would be capable of changing it from 25 to 90 minutes. Therefore, it is evident, as actual experience proved, that a slower setting cement could be obtained by seasoning a 2.0 per cent mixture.

This material also could be plastered to insure the requirements specified for abnormally quick-setting cements, as it is now evident that the ground, weathered clinker if mixed with 3, or better 5, per cent of plaster would remain abnormally quick setting unless subjected to such drastic seasoning as to render the cement practically inert.

The results obtained with this sample again indicate that it is characteristic of the general nature of the commercial product which it represents. Take for instance the representative commercial product recorded in Table A, Appendix I.⁵⁹ It was plastered with an equivalent of 2.7 per cent (1.44 per cent of SO_3 , ignited) of our plaster of Paris, set in 10 minutes and remained quick setting during three months of thorough aëration.

The reason why these three cements behave so differently is because the rate of the reaction of the compounds which cause them to set are not the same. It can readily be realized that the present and future setting properties of a cement depend not only on the quantity and the condition of the free lime and the amount of retarder capable of entering into the reactions involved, but also upon the quantity, character and activity of the setting compounds themselves. Accordingly, in brand L and similar cements we may assume that extremely quick-setting compounds (presumably the dicalcium aluminates and ferrates) are lacking to such an extent that in spite of changes in the condition of the free lime and variations in conditions of heat, a small quantity of retarder is at all times capable of keeping the set within normal limits.

We may also assume that the effect of heat upon the activity of the quick-setting compounds is greater in some cements than in others, and hence the difference between O and K.

We have not encountered cements in which the normal activity of the compounds causing the set was so great that no process of seasoning or plastering was able to produce a normal set, but such cements have frequently been reported from other sources.

However, whatever the influence of chemical composition, the real phenomena entering into the reactions, the natural activity of the setting compounds, and the quantity and condition of the free lime, it is still evident that the method of investigation described in Part III of this paper is an accurate and efficient means of ascertaining the possible

⁵⁹ *This Journal*, Sec. A (1910), 5, 415.

effects of storage on the setting properties of Portland cement which has been plastered with a known amount of retarder.

THE INFLUENCE OF FINENESS ON THE RATE OF SET.

Another subject of considerable importance to both manufacturer and consumer is the influence of fineness upon the rate of set. Generally speaking, it has long been known that the finer a cement is ground the greater is its possible efficiency. Nevertheless, the attempts made to enforce finer grinding met with such decided opposition from the beginning that many cements are able to meet the requirements of our modern standard specification even though they contain 20 per cent and more of inert material which, if ground fine enough, would correspondingly increase their value.

For a long time advocates against fine grinding maintained that if Portland cement was completely pulverized to form an impalpable powder, it would become so active that its set could not be controlled. However, eventually, it became known that, although the general effect of finer grinding is to quicken the set, in some instances this is almost unnoticeable.

However, scientific knowledge upon this subject is extremely limited. This is readily accounted for if we consider that the majority of investigators failed to take into consideration the influence which changes in the condition of the free lime had upon the set. Many endeavored to ascertain the effects of fine grinding by using material obtained by separating the fine from the coarser particles in ordinary Portland cement. Others failed to consider the fact that finer grinding or regrounding often increased the amount of active free lime.

Our work on this problem soon convinced us that the general influence of fine grinding, namely the quickening of the set, is due to the presence of "some undesirable element in the coarser and at present inert particles of the cement which is liberated or rendered active by the grinding."⁶⁰ However, we do not believe that the undesirable element in the coarser and harder particles of Portland cement is "owing to the fact that they are lower in lime and are burned to a high degree of vitrification."

In the first place Meade's conclusion in this respect is based upon doubtful evidence because he did not prove that the coarser particles in cement contained less *combined* lime than the separated, impalpable powder. The usually higher total amount of calcium oxide in the latter is readily accounted for by the fact that the free lime liberated by the grinding, the product into which the free lime has become converted and most of the retarder, are included in the fine powder. Furthermore,

⁶⁰ Meade, R. K., *Am. Soc. Test. Mat.* (1908), 8, 410.

Meade entirely neglected to consider the fact that the coarser particles even in well-seasoned cements usually contain microscopic particles of free lime which remain inactive and anhydrous until their protective coatings of slag or calcium carbonate are destroyed or split open by finer grinding. (See Table VI, Part II.) Obviously, if a cement is reground and tested before the newly liberated calcium oxide has become converted into its hydrate, the heat produced by the slaking of this lime when water is added will tend to quicken the set. Obviously also, if a cement contains material which is inert only because of the coarseness of its particles, and later is reground until this material is fine enough to become active, the amount of retarder in relation to the active cement is decreased by the process of grinding. Both of these influences tend to quicken the set. However, the former can be removed simply by seasoning the cement until the newly liberated calcium oxide, or its equivalent, has hydrated, and it is our experience that after this has been done, reground commercial Portland cements of standard quality usually regain their normal, slow set even though the regrounding at first made them abnormally quick setting.

A characteristic instance in which the influence of the newly liberated free lime was capable in itself of causing a normal cement to become quick setting is given in Table XXXV.

TABLE XXXV.—*The influence of regrounding in the rate of set of cement N.*
(Temperature 27°.5 to 30°.0.)

Time aerated in days.	Cement N, not reground.						
	Fineness.		Specif- ic grav- ity.	Condition of the free lime (microscopic test).	Water required for a nor- mal con- sistency paste.	Time of setting in minutes.	
	200- mesh.	100- mesh.				Initial set.	Final set.
0	76.8	95.2	3.10	CaO and Ca(OH) ₂ -----	Per cent. 20	70	140
3	-----	-----	3.077	Ca(OH) ₂ -----	21	150	280
17	-----	-----	3.012	CaCO ₃ -----	21.5	70	220
30	-----	-----	2.942	do -----	23	30	250
Cement N, reground. ^a							
0	96.7	100	3.10	CaO and Ca(OH) ₂ -----	22	8	15
3	-----	-----	3.077	Ca(OH) ₂ -----	19.5	110	170
14	-----	-----	3.026	CaCO ₃ -----	23	25	150
Cement N aerated 30 days and then reground.							
0	100	100	2.93	CaO and Ca(OH) ₂ -----	22.5	10	160
3	-----	-----	2.922	Ca(OH) ₂ -----	21	30	180

^a The dry cement was reground in an air-tight ball mill.

An instance in which the effect of the newly liberated lime was sufficient to quicken the set, but not to make the reground cement abnormally quick setting, is given in Table XXXVI:

TABLE XXXVI.—*The influence of regrinding on the rate of set of cement G.*

(Temperature 28° to 30°.)

Condition.	Time aerated in days.	Fineness.		Specific gravity.	Condition of the free lime (microscopic test).	Water required for a normal consistency paste.	Time of setting in minutes.	
		200-mesh.	100-mesh.				Initial set.	Final set.
Not reground	0	75.6	91.8	3.10	CaO and Ca(OH) ₂	Per cent. 19.5	130	300
Reground	0	96.0	100.	3.095	More CaO and Ca(OH) ₂ .	22.0	45	150
Reground—1.0 per cent of plaster.	0	×	×	×	do	21.0	100	210
Reground and aerated.	3	×	×	3.04	Ca(OH) ₂	18.5	130	300

The other influence, namely that due to the increase in the amount of active cement can not be removed without seriously injuring the strength of the cement. It can be realized that this influence might be sufficiently great to cause a reground cement to remain quick setting, not only after the newly liberated calcium oxide had become slaked, but also, after additional retarder had been added. However, fortunately most manufacturers have already succeeded in producing a cement which makes such an instance so exceptional that our experience does not include an example.

Therefore, it is evident that the influence of fineness on the rate of set introduces no new or insurmountable factors into the problem of the control of the set, but we are convinced that most manufacturers can control the set of their Portland cement even though it has been ground to an impalpable powder. We also believe that the possibility of so doing will become more universal as the practice of grinding the raw material to a high degree of fineness and of seasoning cement by the most efficient methods, increases.

CONCLUSIONS.

We have attributed the fundamental cause of changes in the setting properties of Portland cement to alterations in the condition of the free lime. Unfortunately, we have found it impossible except in quantities much too small to meet the requirements of experimental purposes to obtain commercial cements which contain no free lime. Such material could only be secured from a few selected clinkers which in no wise

represent the commercial product from which it is taken. Therefore, and because so many influences must be taken into consideration where the set of a cement is concerned, we have been forced to trace causes and results and reason from them step by step, and this process brought about the somewhat voluminous nature of this paper. For the same reason, a brief summary of all the important conclusions arrived at can not be made, the interdependent nature of such conclusions preventing a brief statement of facts.

However, with respect to the control of the setting properties of Portland cement we believe that a method has been devised whereby the manufacturer before packing his cement can ascertain whether its setting properties are controllable, and if so, the minimum amount of retarder required to keep the set within normal or desired limits during the process of ordinary storage.

The manufacturer, especially, should give the subject of partial regauging due consideration, as the first effect of seasoning on cements which have this sudden set is to eliminate the regauging, but to quicken the rate of setting in the commercial application of the product and such cements although apparently slow setting when tested at the mill are especially apt to be quick setting when tested at their destination. So far as our experience goes, this is the main cause of the serious discrepancies which occasionally occur between the reports of the set from the manufacturer and those from the consumer. Nine-tenths of the cements which, when tested in the cement laboratory of the Bureau of Science failed to pass our standard specifications, did so only because they set with abnormal quickness. Fully one-half of these could not have produced a slow-setting paste before they were packed, unless during the process of mixing regauging had taken place to a considerable extent.

It has also been noticed that the policy of some manufacturers has been to plaster their cement with between 0.75 and 1.25 per cent of gypsum. This policy, although evidently purely an economic one, has often caused serious financial losses to both manufacturer and consumer, for we have found that the majority of quick-setting cements only required about 0.5 per cent of additional plaster to make them slow setting.

This work also gives adequate reason for the failure of so many investigators to establish definite facts concerning the effects on the setting properties of various methods of treating the clinker.

Take, for instance, the explanation of H. Spencer Conover⁶¹ to the question, "Why does cement sometimes become quick-setting?" He likens the reactions of the tempering of cement to that of steel, and states that the stability of cement depends to a large extent upon the proportion of *alite* and *celite* to each other. His statements are based upon the results obtained by dividing a sample of clinker into three parts and cooling them in different ways.

⁶¹ *Cement Age* (1905), 3, 479-86.

First, part of the clinker was ground while hot. If mixed immediately with water it set in 2 hours, but upon standing 3 days it turned to a quick-setting cement. Second, part of the clinker was cooled before grinding. This also turned to a quick-setting material after aging 3 days, although not so quick as the first. The third sample was soaked while hot in water for 3 hours and then after drying 3 days, was ground. The resulting cement was slow setting and upon aging 3 days more lengthened its time of set very much. These samples were all ground to pass a 100-mesh sieve and to each 2 per cent of plaster was added.

Conover attributes the slow-setting properties of the quenched clinker to the fact that solidification was brought about so quickly that the excess of aluminate was prevented from separating.

His results, far from indicating that the more quickly the clinker cooled, the more slowly the cement set, only offer additional corroboratory evidence to the conclusions arrived at by our own experiments. Similar results have been obtained at this laboratory merely by treating seasoned and non-seasoned parts of the same ground cement with a fixed amount of plaster. Conover's experiment should be repeated and the cooling of the clinker should be done in such a manner that alterations in the condition of the free lime would either occur to the same extent in all samples or not occur at all.

In this connection it may also be stated that H. K. Bamber,⁸² after an investigation both on a manufacturing and laboratory scale, failed to obtain other than indefinite results of a negative character. However, he found that by grinding the clinker at a temperature of about 92° in the presence of a limited amount of live steam, the cement operated upon was made to take up uniformly throughout a small amount of water (about 1.0 per cent) which could not be expelled except by ignition; that this treatment had an enormous influence on the action of the cement when tested for soundness; that the proportion of gypsum required to be added to produce a slow-setting cement was thereby much reduced; and that by this treatment in conjunction with even small percentages of gypsum, the slowing effect of the combination was maintained.

One per cent of water is capable of hydrating almost 3.0 per cent of lime, and although Bamber failed to give any definite chemical or physical explanation as to the cause of these effects, we do not hesitate to attribute them to the hydration of the lime, as we always obtained similar results by any method of seasoning cement which would convert the calcium oxide into its hydrate.

In Bamber's method the high temperature at which the reaction takes place induces the free lime to slake very quickly and little, if any, calcium carbonate is formed. Consequently, his method is more efficient than the ordinary process of aëration, and therefore the steamed cement maintains its slow-setting properties longer than if the hydration had been brought about by aëration. It is not known whether or not Bamber's process of hydrating the free lime by steam damages to any extent

⁸² *Concrete and Const. Eng.* (190), 4, 196.

the cement itself. Therefore, it is possible that the hydration of the lime in Portland cement might be accomplished still more efficiently and at the same time more economically by seasoning the clinker. We have shown that water has no action on the perfectly sintered or fused clinker and that a wet imperfectly burned clinker seasons more efficiently than a comparatively dry one. Conover's work further suggests that the red-hot clinker should be dropped into water as soon as it leaves the rotary kiln rather than after the clinker has become cold. This not only will produce a softer, more easily ground clinker, but it is also certain that the calcium oxide which had been burned at an extremely high temperature will hydrate more quickly in hot or boiling than in cold water.

The relative efficiencies of these two processes should be carefully investigated.

ILLUSTRATIONS.

PLATE VI.

Photograph of a cement which failed to pass the steam test because of the inertness of its finest particles.

TEXT FIGURES.

- FIG. 16. Set curves obtained from cement O_1 which show the characteristic effects of gauging a non-seasoned, non-plastered Portland cement with different quantities of water.
17. Set curves obtained from cements O_1 , K and L which show the unlike influences of small amounts of plaster on the setting properties of different non-seasoned Portland cements.
18. Diagram which shows quantitatively the unlike influence of small amounts of plaster on the plasticity and time of initial set of different non-seasoned Portland cements.
19. Set curves obtained from cement K which show that the effects produced by the addition of small amounts of plaster are influenced by the extent to which the clinker has seasoned.
20. Diagram showing the effects of fineness upon the setting properties of Portland cement which has been subjected to thorough and prolonged aëration.
21. Diagram which shows the extent to which the effects of thorough aëration on the setting properties of O_1 cement were influenced by the quantity of plaster used.
22. Diagram which shows quantitatively the unlike effects produced by adding small amounts of plaster to cement K before and after the clinker had seasoned.



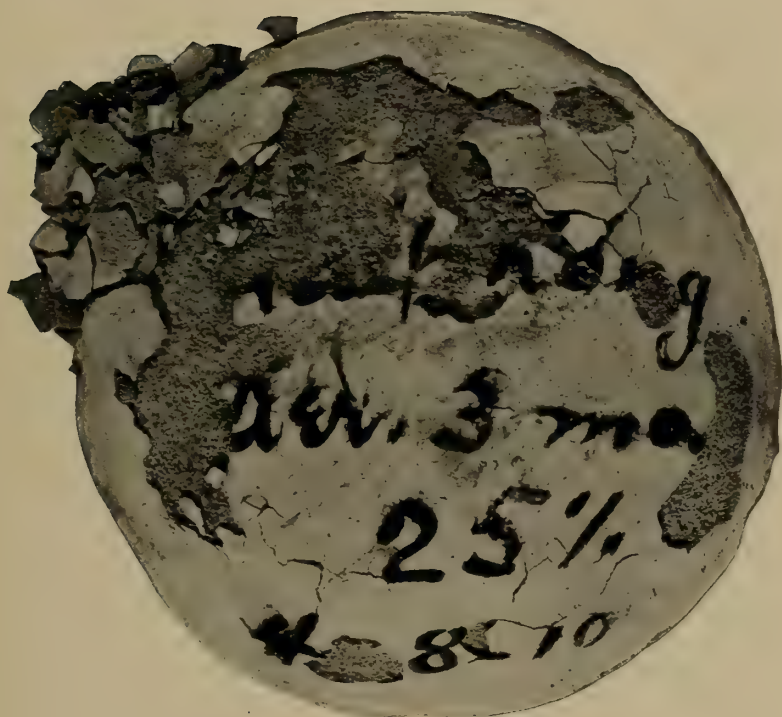


PLATE VI.

ON THE FORMATION OF CERTAIN ALKALOIDAL PERIODIDES—PRELIMINARY INVESTIGATION.

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INTRODUCTION.

The systematic investigation of the periodides of the alkaloids was begun in 1869 by Jorgensen.¹ In 1887 Geuther² presented a general review of the subject and a classification of all the periodides then known. More recently, classifications of the periodides of both organic and inorganic bases, and of other perhalides have been made by A. B. Prescott³ and M. Gomberg.⁴

The quantitative determination of vegetable bases by the precipitation of their periodides in aqueous solution was first attempted by R. Wagner⁵ who employed an $\frac{N}{10}$ aqueous solution of iodine and potassium iodide, since known as Wagner's reagent. A similar solution had already been adopted by Bouchardat.⁶ Wagner gave a list of organic bases which might be precipitated, and stated that caffeine, theobromine, piperine and urea gave no precipitates. A quantitative study was made with the sulphates of quinine and cinchonine, showing that under approximately similar conditions the alkaloids required a definite amount of iodine for precipitation and that empirical factors could be established for the determination of such organic bases as gave insoluble periodides.

In 1885 Schweissinger⁷ found that the method gave good results with strychnine, even in the presence of free mineral acid or alcohol, but was unsatisfactory with brucine. He recommended the addition of the iodine reagent in slight excess to avoid high results, the rapid filtration of the solution and the minimization of the volume of water employed in washing the precipitate to avoid as far as possible any solution or decomposition of the periodide.

¹ *Journ. f. prakt. Chem.* (1869), II, 2, 433.

² *Ann. d. Chem.* (Liebi) (1887), 240, 66.

³ *Journ. Am. Chem. Soc.* (1895), 17, 775.

⁴ *Ibid.* (1896), 18, 347.

⁵ *Dingler's polytech. Journ.* 161, 40.

Ztschr. f. anal. Chem. (1862), 1, 102.

⁶ *Compt. rend. Acad. sci.* (1839), 9, 435.

⁷ *Arch. d. Pharm.* (1885), 223, 615.

The generally accepted theory of the composition and mechanism of formation of these precipitates was that they were di-iodides of the alkaloidal hydriodide, deriving their "superiodide atoms" from the free iodine of the solution and their hydriodic acid by metathesis from potassium iodide and whatever acid was present. Schweissinger's results with strychnine were in general agreement with the theory.

In 1895 Kippenberger⁸ investigated the availability of Wagner's reagent in the estimation of a number of alkaloids. He obtained precipitates which corresponded to the tri-iodide formula by the addition of a slight excess of $\frac{N}{20}$ iodine solution to morphine in neutral salt solution and to acid solutions of the hydrochlorides of a number of alkaloids. He assumed that all of the iodine of the periodides was derived from the free iodine of the solution, the hydriodic acid radicles being produced according to the reaction $2I + 2H_2O = 2HI + H_2O_2$. Considerable emphasis was laid on the proper concentration of potassium iodide in the reagent. When the smallest possible amount was used, the results were irregular, the precipitates containing free iodine in greater or less degree depending on the excess of reagent employed. Kippenberger's final method consisted in adding a solution of silver iodide in potassium iodide to that of the alkaloid which contained the smallest possible excess of acid, employing only an amount of the iodide equivalent to, or slightly in excess of the acid used. The alkaloid was then precipitated with a small excess of an $\frac{N}{20}$ iodine solution. In this manner tri-iodides were obtained with a number of alkaloids, although quinine gave a pentiodide.

A few years later M. Stolz⁹ declared Kippenberger's method to be worthless, his analytical data to be untrustworthy and his theory of the formation of periodides to be unsound.

A lengthy controversy ensued,¹⁰ in the course of which Kippenberger stated that the discrepancy between his work and that of Stolz was due to the employment by the latter of a solution containing too much potassium iodide. He maintained, in defense of his theory, that the iodine of the hydriodic acid group came from the free iodine of the solution, that the periodide of narcotine may be produced by the action of iodine without the presence of potassium iodide. He admitted the inaccuracies of his method, but still recommended it as practical in case the reagent was standardized against the alkaloids under conditions approximating those of the subsequent determinations.

In 1896 Gomberg¹¹ brought forward a method for the determination of caffeine. Tarnit¹² had already shown that caffeine in a solution of mineral acid is precipitated by Wagner's reagent even at very great dilution and Shaw¹³ had obtained similar results with theobromine. Gomberg showed that in the presence of mineral acids the caffeine precipitates, even under widely varying conditions of precipitation, were of a constant composition, corresponding to the pentiodide.

⁸ *Ztschr. f. anal. Chem.* (1895), **34**, 317. *Ibid.* (1896), **35**, 10. *Ibid.*, 422.

⁹ *Arch. d. Pharm.* (1889), **237**, 71.

¹⁰ Kippenberger, *Ztschr. f. anal. Chem.* (1899), **38**, 230. Stolz, *Ibid.*, 278. Kippenberger, *Ibid.*, 280. Kippenberger, *Arch. d. Pharm.* (1900), **238**, 135. Stolz, *Ibid.*, 301.

¹¹ *Journ. Am. Chem. Soc.* (1896), **18**, 331.

¹² *Journ. d. Pharm.*, **28**, 433, and 490.

¹³ *Journ. Chem. Soc. London* (1896), **69**, 102.

His method has apparently given general satisfaction, although Kippenberger¹⁴ maintains that a considerable amount of free acid is essential and even then, unless a marked excess of iodine is used, complete precipitation can not be obtained. He states that if the caffeine is first converted into its hydriodide the tri-iodide instead of the penta-iodide is precipitated.

In 1898 Prescott and Gordin¹⁵ published a paper on the volumetric estimation of alkaloids as higher periodides. It was already known from the work of Jorgensen and others that many alkaloids were capable of forming more than one periodide under different conditions. Previous quantitative methods had consisted of adding the iodine solution in slight excess to the solution of the alkaloid. If, according to Prescott and Gordin, the alkaloidal solution is added to that of the iodine, keeping a large excess of iodine always present, the higher periodide as a rule is formed. Applying this general method they state that strychnine, brucine and aconitine are precipitated as heptiodides and atropine as an enne-iodide. Morphine, whatever the conditions of precipitation, according to these authors always forms the tetriodide in aqueous solution.

In the course of their investigations, they showed that in the precipitation of atropine enneiodide, the potassium iodide of the reagent took an active part in furnishing the iodine for the hydriodic acid group of the periodide molecule. In 1899 Gordin¹⁶ gave a method for the alkalimetric estimation of salt-forming alkaloids, based on the supposition that, although periodides contain variable amounts of additive iodine, they all have one molecule of hydriodic acid for each molecule of alkaloid. The method consisted in dissolving the alkaloid in a known amount of dilute mineral acid, precipitating the periodide with an excess of Wagner's reagent, and titrating the acid remaining in the filtrate with phenolphthalein as indicator. Several alkaloids gave good results, but it was found neither colchicine nor beriberine, which does not carry down any acid, could be estimated. According to Kippenberger,¹⁷ results by this method are so profoundly influenced by the proportion of free acid as well as that of potassium iodide in the reagent that they are useless for quantitative purposes, and attention was also called to the fact that many of the impurities which in actual work would inevitably be present would combine with the acid and be estimated as alkaloids. Recently Garsed and Collie¹⁸ found that a black, tarry precipitate was thrown down on adding a one per cent neutral solution of cocaine hydrochloride to Wagner's reagent in which the molar ratio of cocaine to the equivalent of iodine varied with the excess of reagent used from 1:3.4 to 1:5. A considerable amount of iodine could be extracted from these compounds with ether, leaving a crystalline residue corresponding in composition to the tri-iodide. With less concentrated solutions the molar ratio became as great as 1:2.3. However, if the reagent were added to the cocaine solution, a brown flocculent precipitate was obtained which had the composition of the tri-iodide. In order to obtain good results it was found essential to add the iodine solution slowly.

It is plain to judge from this historical review of the more important investigations relating to the employment of periodides in the

¹⁴ *Ztschr. f. anal. Chem.* (1900), **39**, 435.

¹⁵ *Journ. Am. Chem. Soc.* (1898), **20**, 706. *Arch. d. Pharm.* (1899), **237**, 380.

¹⁶ *Pharm. Arch.*, **2**, 313. *Arch. d. Pharm.* (1900), **238**, 335. *Ibid.* (1901), **239**, 645.

¹⁷ *Ztschr. f. anal. Chem.* (1903), **42**, 101.

¹⁸ *Journ. Chem. Soc. London* (1907), **79**, 675.

estimation of the alkaloids, that the whole question is still in confusion and must so remain until the nature of the precipitates and the mechanism of the reaction under varied conditions and with different classes of alkaloids have been more thoroughly studied.

EXPERIMENTAL.

Some years ago H. D. Gibbs, of the Bureau of Science, obtained peculiar results while testing samples of prepared smoking opium seized under Act ¹⁹ No. 1761 of the Philippine Commission and submitted to this laboratory for examination.

The iodic acid test ²⁰ for morphine often gave a chloroform solution which was brown in color and not at all characteristic of solutions of iodine in this solvent. The failure of the test was traced to an incomplete separation of morphine from codeine. It was found that, while small amounts of codeine in the solution do not interfere, the test is always valueless when the concentration of the morphine is not considerably in excess of that of the codeine, or when the latter alkaloid is present in large amounts, irrespective of the concentration of the morphine, or when the amount of codeine present is greatly in excess of the amount of iodine liberated by the morphine. It seems probable from these observations that the tendency which codeine has to combine with iodine is so great that the liberated halogen will not, as such, pass into the chloroform and impart the characteristic color to that solvent, and also that codeine has a greater avidity for iodine than morphine.

Additional evidence, which would appear to corroborate this conclusion, will be presented later.

An investigation of some of the relations of these alkaloids was therefore undertaken, and since heroin is so closely allied to them, that alkaloid was also included in the study.

Solutions of the sulphates of morphine, codeine, and heroin in distilled water were made to approximately 1 per cent strength, and $\frac{N}{10}$ solutions of sodium thiosulphate and iodine in potassium iodide prepared. A few preliminary precipitations gave results which, although apparently anomalous, were still capable of a certain correlation and indicated that the iodine content of the precipitate was in large measure dependent on the concentration of iodine in the solution.

A series of determinations was then undertaken in the following manner:

In each experiment, 5 cubic centimeters of the alkaloidal solution were

¹⁹ This act forbids the importation and sale, except for medicinal purposes, of opium and cocaine and their derivatives.

²⁰ Blyth, *Poisons: Their Effects and Detection*, London, 4 Ed. (1906), 300. This test depends upon the fact that morphine will set iodine free from iodic acid. Codeine and heroin do not do this.

pipetted into a suitable glass stoppered bottle, approximately 50 cubic centimeters of $\frac{N}{10}$ sulphuric acid added, the desired amount of iodine solution run in and the volume made up to approximately 200 cubic centimeters with distilled water. The bottle was then thoroughly shaken and set aside over night. The final determination was made by filtering the solution through abestos, rapidly washing the bottle and precipitate with a small amount of water and determining the residual free iodine in the combined filtrates by titration with thiosulphate solution.

The physical characteristics of the precipitates are of interest. As a rule they come down as finely divided compounds of a light reddish-brown color which quickly becomes darker in the presence of any considerable excess of iodine. When the concentration of iodine in the solution is low, the codeine precipitates are plainly crystalline, and a tendency toward the formation of crystals in the morphine solutions is also observed, although no well-defined individuals are found, while the heroin precipitates are all apparently amorphous. With comparatively high concentrations of iodine the precipitates of all three alkaloids are black and of a pitchy or even oily consistency. The data from these experiments are given in the following table:

TABLE I.—*Formation of the periodides of morphine, codeine, and heroin in acid solution.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Grams alkaloid per cubic centimeter solution.	Iodine solution.			Excess iodine + iodine used up.	Atoms of iodine—	
			Run in.	Used up.	Excess.		Per molecule alkaloid.	Combined with 1 molecule of alkaloid in periodide.
			cc.	cc.	cc.			
1	.03971	.00016	6.37	1.49	4.88	3.27	4.57	1.07
2	.03971	.00016	31.71	5.31	26.40	4.97	22.77	3.81
3	.03971	.00016	43.44	6.95	36.49	5.23	31.78	4.99
4	.03971	.00016	63.11	7.95	55.16	6.93	45.32	5.71
5	.03971	.00016	126.22	10.90	115.32	10.59	92.65	7.83

CODEINE.

6	.03894	.00017	6.31	4.12	2.19	0.53	4.84	3.17
7	.03894	.00017	26.43	8.14	18.29	2.24	20.31	6.25
8	.03894	.00017	44.63	10.28	34.35	3.34	34.29	7.90
9	.03894	.00017	63.07	11.72	51.35	4.38	48.45	9.00
10	.03894	.00017	126.22	15.56	110.66	7.11	96.97	11.95

TABLE I.—*Formation of the periodides of morphine, etc.—Continued.*

HEROIN.

Number of experiment.	Grams alkaloid.	Grams alkaloid per cubic centimeter solution.	Iodine solution.			Excess iodine + iodine used up.	Atoms of iodine—	
			Run in.	Used up.	Excess.		Per molecule alkaloid.	Combined with 1 molecule of alkaloid in periodide.
			cc.	cc.	cc.			
11	.05088	.00017	4.04	0.83	3.21	3.99	2.93	0.60
12	.05088	.00017	6.90	2.17	4.73	2.18	5.01	1.57
13	.05088	.00017	6.92	2.20	4.72	2.14	5.02	1.59
14	.05088	.00017	12.71	4.85	7.86	1.62	9.22	3.52
15	.05088	.00017	25.24	7.96	17.28	2.16	18.30	5.78
16	.05088	.00017	32.99	8.88	24.11	2.71	23.94	6.44
17	.05088	.00017	44.47	9.79	34.68	3.54	32.26	7.10
18	.05088	.00017	62.69	10.10	52.59	5.21	45.49	7.23
19	.05088	.00017	126.22	10.58	115.64	10.93	93.76	7.67

The free acidity of the solutions was approximately 0.25 gram sulphuric acid in each experiment.

The ratio of the equivalents of additive iodine to one molecule of alkaloid in the compound or compounds resulting from the reaction was calculated in each experiment from the weight of free iodine removed from the solution and the weight of alkaloid originally present. No tests were made to ascertain the degree of completeness of the precipitation of the alkaloid. The solubility of periodides is known to depend in a measure on the relative amounts of additive iodine in the compound, the hydriodides being soluble and the solubility of the periodides decreasing as the amount of additive iodine is increased so that it was considered probable, at least in those experiments where the concentration of iodine was low, that the precipitation of the alkaloid was incomplete and the appearance of the precipitates alone seemed to justify this conclusion. The question of the influence of this effect on the results obtained and the question of the accuracy of the results in general will be considered later.

A graphic presentation of the data is given in the curves of figures 1 and 2. It will be seen that the amounts of free iodine which combine with the alkaloids are dependent in a perfectly regular degree upon the concentrations of free iodine in the solutions. The reactions of morphine and codeine differ only in degree, but heroin, on the other hand, presents some marked peculiarities. With heroin solutions and

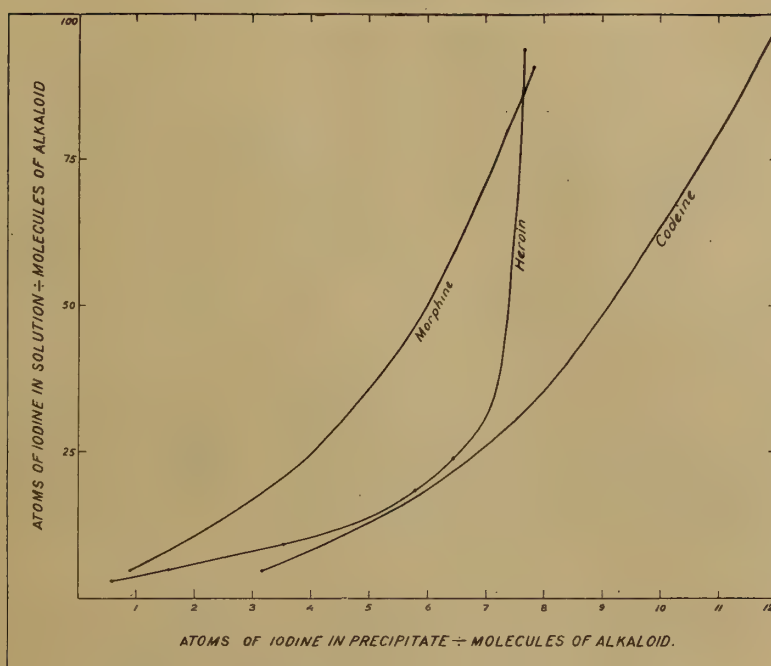


FIG. 1.

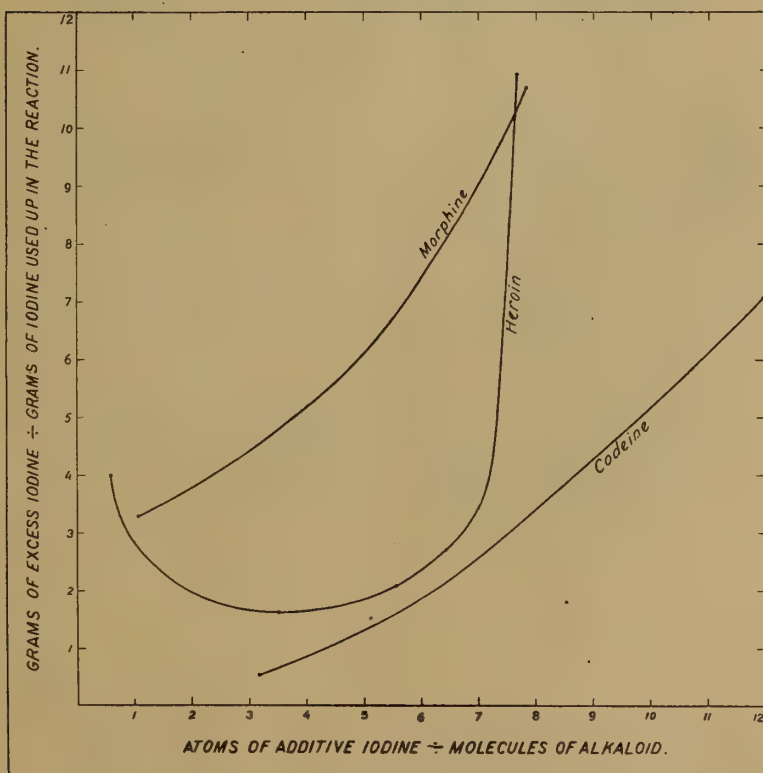


FIG. 2.

low concentration of iodine an increase in the concentration of the iodine in the solution is attended by a greater increase in the iodine in the reaction product than is the case with the other alkaloids, while a point is soon reached with higher concentrations where further increment in iodine concentration has but little effect. This may possibly be interpreted as evidence of a tendency toward the formation of a definite periodide, although no concomitant tendency toward a definite crystal form was observed. No indication was apparent of an inclination toward the formation of any definite periodides in the experiments with morphine and codeine.

A series of experiments was then made to determine in how far the precipitation of the periodides in acid solutions was influenced by various factors. In this work, a new iodine solution was employed and the following data are not strictly comparable with those given in Table I. In every precipitation the solution was made up to about 250 cubic centimeters, so that the concentration of heroin was somewhat greater than that of the other alkaloids.

TABLE II.—*Influence of the concentration of potassium iodide in the solution.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Gram KI (approximate.)	Grams H ₂ SO ₄ free acidity.	$\frac{N}{10}$ iodine—		Atoms iodine per molecule of alkaloid.
				Added.	Used up.	
				cc.	cc.	
20	0.08971	0.270	0.25	14.96	1.64	1.17
21	0.08971	0.279	0.25	14.96	1.56	1.12
22	0.08971	0.297	0.25	14.96	1.23	0.88
23	0.08971	0.540	0.25	14.96	0.35	0.25

CODEINE.

24	0.3894	0.279	0.25	14.96	4.40	3.38
25	0.3894	0.297	0.25	14.96	4.21	3.23
26	0.3894	0.540	0.25	14.96	3.74	2.87

HEROIN.

27	0.05088	0.270	0.25	14.96	5.07	3.63
28	0.05088	0.279	0.25	14.96	5.01	3.68
29	0.05088	0.297	0.25	14.96	4.14	3.00
30	0.05088	0.540	0.25	14.96	3.29	2.39

TABLE III.—*Influence of absolute concentration.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Free acidity, grams H_2SO_4 .	Concentration.		$\frac{N}{10}$ iodine—		Atoms of iodine per molecule alkaloid.
			Initial. ^a	Final. ^b	Added.	Used up.	
			cc.	cc.	cc.	cc.	
31	0.03971	0.25	80	100	14.96	4.12	2.96
32	0.03971	0.25	130	250	14.96	1.65	1.18
33	0.03971	0.25	280	600	14.96	1.53	1.09

CODEINE.

34	0.3894	0.25	80	100	14.96	5.92	4.55
35	0.3894	0.25	130	250	14.96	4.73	3.63
36	0.3894	0.25	280	600	14.96	2.99	2.29

HEROIN.

37	0.05088	0.25	80	100	14.96	6.81	4.94
38	0.05088	0.25	130	250	14.96	5.04	3.66

^a The figures represent the volume of solution at the moment of precipitation.^b The figures represent the volume of solution after dilution.TABLE IV.—*Influence of time of standing.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Free acidity, grams H_2SO_4 .	Time of standing.	$\frac{N}{10}$ iodine—		Atoms of iodine per molecule of alkaloid.
				Added.	Used up.	
				cc.	cc.	
39	0.3971	0.25	16 to 24 hours -----	14.96	1.64	1.17
40	0.3971	0.25	5 minutes -----	14.96	1.06	.76

CODEINE.

41	0.07788	0.25	5 minutes -----	25.53	9.28	3.56
42	0.07788	0.25	16 to 24 hours -----	24.93	10.92	4.19
43	0.07788	0.25	72 hours -----	24.93	10.91	4.19

TABLE V.—*Influence of method of precipitation.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Free acidity, grams H_2SO_4 .	Method of precipitation.	$\frac{N}{10}$ iodine—		Atoms of iodine per molecule of alkaloid.
				Added.	Used up.	
				cc.	cc.	
44	0.03971	0.25	Iodine added to alkaloid.	14.96	1.65	1.18
45	0.03971	0.25	Alkaloid added to iodine.	14.96	1.64	1.18

CODEINE.

46	0.03894	0.25	Iodine added to alkaloid.	14.96	4.74	3.64
47	0.03894	0.25	Alkaloid added to iodine.	14.96	4.72	3.63

HEROIN.

48	0.05088	0.25	Iodine added to alkaloid.	14.96	4.91	3.56
49	0.05088	0.25	Alkaloid added to iodine.	14.96	4.96	3.60

TABLE VI.—*Influence of free acidity.*

MORPHINE.

Number of experiment.	Grams of alkaloid.	Free acidity, grams H_2SO_4 .	$\frac{N}{10}$ iodine—		Atoms of iodine per molecule of alkaloid.
			Added.	Used up.	
			cc.	cc.	
50	0.3971	0.00	14.96	6.12	4.40
51	0.3971	0.12	14.96	1.88	1.35
52	0.3971	0.25	14.96	1.64	1.17
53	0.3971	0.49	14.96	1.20	0.86

CODEINE.

54	0.03994	0.00	14.96	5.33	4.09
55	0.03994	0.12	14.96	4.81	3.69
56	0.03994	0.25	14.96	4.76	3.66
57	0.03994	0.49	14.96	4.84	3.72

HEROIN.

58	0.05088	0.00	14.96	7.07	5.13
59	0.05088	0.12	14.96	5.37	3.90
60	0.05088	0.25	14.96	5.07	3.68
61	0.05088	0.49	14.96	5.00	3.63

TABLE VII.—*Influence of temperature.*

MORPHINE.

Number of experiment.	Grams alkaloid.	Free acidity, grams H_2SO_4 .	Temperature.	$\frac{N}{10}$ iodine—		Atoms of iodine per molecule of alkaloid.
				Added.	Used up.	
62	0.03971	0.25	0	14.96	3.60	2.58
63	0.03971	0.25	30	14.96	1.64	1.17

CODEINE.

64	0.3894	0.25	0	14.96	5.98	4.59
65	0.3894	0.25	30	14.96	4.72	3.63

HEROIN.

66	0.5088	0.25	0	14.96	5.33	3.87
67	0.5088	0.25	30	14.96	5.07	3.68

With all three alkaloids, the amount of iodine which enters into the periodide varies directly with the absolute concentration of the solution and inversely with a rise in temperature or an increase in the concentration of sulphuric acid or potassium iodide in the solution. The experiments also indicate that it is immaterial which solution is added to the other in the precipitation and that equilibrium is reached in a comparatively short period. Certain determinations not included in the table showed that half an hour is sufficient, especially if the solution is occasionally agitated.

All of the codeine precipitates were plainly crystalline, and the largest and best defined crystals were obtained in experiment number 36 under conditions of low absolute concentration. None of the heroin precipitates appeared to crystallize and only two definitely crystalline morphine compounds were obtained, one in experiment number 31 with a concentrated solution and the other in experiment number 62 at a low temperature.

According to the accepted theory of the use of Wagner's reagent, a certain amount of free iodine enters into the alkaloidal periodide precipitate and this amount may be accurately determined by the titration with thiosulphate of the free iodine remaining in the filtrate and subtracting this residual free iodine from the amount known to have been originally present. The following experiments will serve to demonstrate the fallacy of this conclusion.

TABLE VIII.—*Experiments with morphine sulphate under circumstances unfavorable for periodide precipitation.*

Number of experiment.	Grams alkaloid.	Volume of solution.	Alcohol present.	Free acidity grams H_2SO_4 .	$\frac{N}{10}$ iodine—		Atoms of iodine per molecule of alkaloid.
					Added.	Used up.	
			cc.		cc.	cc.	
68	0.050	200	None.	0.25	3.00	1.04	0.59
69	0.050	200	None.	None.	3.00	2.95	1.68
70	0.050	200	10	None.	9.93	4.92	2.81
71	0.050	200	50	None.	10.02	2.49	1.42
72	0.050	200	100	None.	10.04	0.91	0.52

In only one experiment, number 70, was any precipitate obtained, and it was shown by a prolonged extraction of this with an excess of thiosulphate solution that of the total amount of iodine which had been removed from the "free" state slightly more than 65 per cent had remained in the filtrate. In the other experiments in which the solutions remained perfectly clear, varying amounts of free iodine were used up. The end point was in every case perfectly distinct and it was plain that soluble compounds of morphine and iodine had been formed. A check was made on experiment number 69 by adding iodine solution, drop by drop, to that of an alkaloidal solution which had been treated with starch and diluted to nearly a volume of 200 cubic centimeters. The amount of iodine which was required to give a permanent blue color corresponded to the ratio of 1.64 atoms of iodine per molecule of morphine. No precipitate was formed.

This fact, that there are soluble compounds of iodine and morphine which will not give up their free iodine upon titration with thiosulphate, is of the greatest importance.

It would appear that a certain amount of the free iodine which enters into combination with the base must be bound to it much more intimately than would be the case if it were merely additive to the hydriodide radical, or it would otherwise react with the thiosulphate.

Prescott and Gordin²¹ have investigated the mechanism of the reaction of atropine with Wagner's reagent and found that an amount of potassium iodide is used up by the reaction equivalent to that required by theory for the formation of the hydriodic acid group of the periodide. They did not attempt to show that all the "free" iodine expended in the reaction was held in the "additive" condition and could be recovered by titration with thiosulphate.

In the course of the present work a number of similar experiments were undertaken in order to throw light on nature of the reactions with morphine and heroin.

²¹ *Journ. Am. Chem. Soc.* (1898), 20, 720.

The amount of free iodine in the reagent was determined by titration with thiosulphate and the total iodine by reduction with zinc dust and the precipitation of silver iodide in the resulting colorless solution. The alkaloid was precipitated in acid solution in the usual manner and after equilibrium had been established was filtered rapidly. The additive iodine of the precipitate was found by solution in alcohol and titration with thiosulphate and the amounts of free and bound iodine expended in the formation in the periodide estimated by the determination of the residual free and total iodine in aliquot portions of the filtrate. These experiments were carried out with two different reagents and the conditions of the tests were varied in several ways. The following experiments will serve to indicate the nature of the results obtained:

Experiment A:

Volume of solution, cubic centimeters	500
Morphine, grams	0.050
Free iodine, grams	0.6114
Total iodine, grams	1.2310
Free H ₂ SO ₄ , grams	0.25
Free iodine in filtrate, grams	0.4721
Total iodine in filtrate, grams	1.0670
Free iodine in precipitate, grams	0.0980

Experiment B:

Volume of solution, cubic centimeters	500
Heroin, grams	0.0568
Free iodine, grams	0.6114
Total iodine, grams	1.231
Free H ₂ SO ₄ , grams	0.25
Free iodine in filtrate, grams	0.4793
Total iodine in filtrate, grams	1.0978
Free iodine in precipitate, grams	0.0860

Experiment C:

Volume of solution, cubic centimeters	500
Heroin present, grams	0.0568
Free iodine present, grams	1.2227
Total iodine present, grams	2.461
Free H ₂ SO ₄ , grams	0.25
Free iodine in filtrate, grams	1.097
Total iodine in filtrate, grams	2.311
Free iodine in precipitate, grams	0.1005

In general the results obtained were very variable and of somewhat questionable value. The amount of "bound" iodine or potassium iodide expended in the reaction seldom corresponded to the amount demanded by theory and in a number of experiments was apparently negative in value, a condition which was taken to indicate that precipitation was incomplete and that compounds of iodine and alkaloid existed in the filtrate. These experiments have been cited mainly because they substantiate the claim that the free iodine of the reagent used up in the precipitation can not again be wholly recovered by titration with thiosulphate. In every experiment considerably more free iodine was present in the original solution than was subsequently found in the titration of the filtrate and dissolved precipitate, the magnitude of the difference amounting to between two and three atoms of iodine per molecule of alkaloid in the majority of cases.

These last experiments were also taken to indicate that the precipitation of the alkaloid is, under certain conditions, incomplete, a conclusion already reached from other considerations, and it was suggested that curves shown in plates numbered 1 and 2 might to a large extent be merely solubility curves of the periodides. It has been shown that the apparent atomic ratio of iodine to base could be diminished in a number of ways, and as, for instance, by increasing the concentration of potassium iodide in the solution, which would increase the solubility of the precipitate. But it has also been demonstrated (see experiments numbered 68 to 72) that the atomic ratio of iodine to base could also be diminished by such means even when no precipitate was present, and also that the recovery of free iodine from such soluble compounds was impossible. While, therefore, it must be admitted that with low concentrations of iodine the precipitation is incomplete, it is very questionable whether any great error is introduced by reason of that fact and it seems probable that the curves give a fairly accurate representation of the actual reaction.

It has been shown that a portion of the additive iodine expended in the reaction can not again be recovered with thiosulphate, the presumption being that it is bound to the alkaloid in some intimate manner. It is hardly possible that this bonding should be of the simple nature represented by the theory. A compound such as $\text{alkaloid} \cdot \text{HI} \cdot \text{I}_x$ would not be expected to retain its additive iodine with such tenacity, nor would it be colorless. It is apparently necessary to assume that the reaction is more complicated than has been supposed.

In view of these experiments the attempt to employ Wagner's reagent for the quantitative estimation of these alkaloids in acid solution would appear to be impracticable. It is not difficult to understand why this method has given rise to so much controversy, and the statement emphasized by Prescott and Gordin²² that in acidulated aqueous solutions morphine is always precipitated as a tetraiodide is not easy to understand.

The results obtained with neutral salt solutions of these alkaloids are also variable, as is indicated by experiments numbered 69 to 72. A few qualitative tests moreover served to show that under these conditions, just as in acid solutions, the amount of iodine in the precipitates increases with the concentration of iodine in the solution.

That certain alkaloids do form definite crystalline compounds in a quantitative manner with this reagent appears to be true and the tendency in a number of cases seems to be to form the tri- and penta-iodides. In this connection it is interesting to note the results of the investigations of Bray and MacKay²³ upon aqueous solutions of iodine in potassium iodide.

²² *Journ. Amer. Chem. Soc.* (1898), **20**, 717.

²³ *Ibid.* (1910), **22**, 914.

These authors show that a large part of the dissolved iodine is in the form of the tri-iodide of potassium, while smaller quantities are present as the penta-iodide. They state: "This result evidently indicates that a small amount of poly-iodide higher than KI_3 is present. If we consider it to be only KI_5 , then we have:

$$C\Sigma I_5 = 0.080 \text{ and } C\Sigma I_3 = 0.582.$$

[The total concentration of the potassium salt present in other forms than potassium iodide is 0.662 mols per liter.]

"Thus we reach a conclusion similar to Laurie, that a large part of the dissolved iodine in the normal potassium iodide solution saturated with iodine is present as tri-iodide. A similar treatment of the remaining measurements shows that the amount of higher poly-iodide decreases as the potassium iodide concentration is decreased, and becomes negligible in the neighborhood of the 0.1 normal solution."

This work is also significant in connection with the results obtained by precipitating the alkaloidal periodides with a solution of iodine in potassium iodide in which the concentration of potassium iodide varies greatly. (See Table II.) The decrease in the amount of iodine entering into the precipitate with the increase in concentration of potassium iodide may be due to the solubility of the alkaloidal periodide in potassium iodide solution; or to the increased reluctance of the poly-iodide to give up the iodine to the alkaloid.

Throughout this paper the term free iodine is used. This should be read to mean *the iodine present in the form of poly-iodides* and reacting with thiosulphate solution. If it is true, as stated by Bray and MacKay, that the hydrolytic reaction $I_2 + H_2O = HIO + H^+ + I^-$ is almost completely driven back in the presence of the dilute acid, and also an iodide, it is evident that it can be ignored in a consideration of the formation of the alkaloidal periodides in this work.

THE ACTION OF WAGNER'S REAGENT WITH SOLUTIONS OF THE FREE ALKALOIDS.

The question of the action of Wagner's reagent upon aqueous solutions of the free alkaloids, so far as I am aware, has been very little studied. It is known that certain alkaloids, notably caffeine, are not precipitated under these conditions and Gomberg²⁴ states that others, including morphine, strychnine, and atropine, are so precipitated.

EXPERIMENTAL.

MORPHINE.

A number of qualitative tests demonstrated that Wagner's reagent will precipitate morphine from very dilute solutions.

²⁴ *Ibid.* (1898), 18, 335.

CODEINE.

The following quantitative determinations were made with a solution of pure codeine in water. In each experiment the solution was made up to a volume of 200 cubic centimeters.

TABLE IX.—*Action of Wagner's reagent with aqueous solutions of codeine.*

Number of experiment.	Grams alkaloid.	N 10 iodine—		Atoms of iodine per molecule of codeine in—	
		Added.	Used up.	Solution.	Periodide.
		cc.	cc.		
73	0.03823	2.01	0.17	1.56	0.14
74	0.03823	2.01	1.49	1.56	1.16
75	0.03823	2.01	1.39	1.56	1.08
76	0.03823	5.14	2.70	4.02	2.12
77	0.03823	10.05	5.69	7.86	2.46
78	0.03823	10.09	5.93	7.89	2.64
79	0.03823	15.35	8.07	12.04	6.32
80	0.03823	15.27	8.07	11.94	6.32
81	0.03823	20.33	8.72	15.89	6.82
82	0.03823	30.48	9.38	23.83	7.34
83	0.03823	50.25	10.69	39.32	8.36
84	0.03823	100.50	15.90	78.64	12.44
85	0.03823	145.22	18.46	113.62	14.44

It will be seen that the amount of iodine which combines with the alkaloid is dependent in a more or less regular degree on the concentration of iodine in the solution. In experiments numbered 73, 74, and 75, of which number 73 was made with 0.25 gram of sulphuric acid and is included in the table merely for purposes of comparison, no precipitates were formed. In the others, precipitates were obtained which, in a general way, resembled those from acid solutions. However, these compounds were not crystalline, and the accuracy of the work was somewhat impaired because it was impossible to secure absolutely clear filtrates in the determinations with the higher concentrations of iodine.

HEROIN.

A similar series of determinations was made with a solution of pure heroin in distilled water. The solubility of this alkaloid at room temperature (about 30°) was found to be approximately one part in twelve hundred of water. In the present work, the concentration of heroin was only one part in twenty-five thousand, yet very decided precipitates were obtained and a test with one part in two hundred and fifty thousand gave a perceptible cloudiness, observable through a considerable layer of solution. Wagner's reagent, therefore, gives an extremely delicate qualitative test for heroin in the absence of acids.

Very similar results were secured with a solution of bromine in potassium bromide.

TABLE X.—*Action of Wagner's reagent with aqueous solutions of heroin.*

Number of experiment.	Grams alkaloid.	N $\frac{10}{10}$ iodine—		Atoms of iodine per molecule of alkaloid in—	
		Added.	Used up.	Solution.	Periodide.
		cc.	cc.		
86	0.0084	1.00	0.72	4.4	3.16
87	0.0084	1.89	1.10	8.3	4.83
88	0.0084	5.72	1.69	25.1	7.43
89	0.0084	10.05	2.08	44.2	9.14
90	0.0084	15.63	2.34	68.7	10.28
91	0.0084	25.72	2.92	113	12.83
92	0.0084	50.87	3.16	223	12.89
93	0.0084	100.74	6.17	446	27.89
94	0.0084	100.74	5.48	446	24.08

It is evident that with heroin also, the amount of iodine combining with the alkaloid is dependent on the concentration of iodine in the solution. The precipitates were apparently similar to those obtained in acid solution. As was the case with codeine, clear filtrates were secured only with low concentrations of iodine and the results must consequently be considered as somewhat inaccurate.

The following determinations, made with the same heroin solution, are of interest in further defining the effect of the presence of acid:

TABLE XI.—*Influence of acidity.*

Number of experiment.	Grams alkaloid.	N $\frac{10}{10}$ iodine—		Remarks.	Atoms iodine per molecule in periodide.
		Added.	Used up.		
		cc.	cc.		
87	0.0084	1.89	1.10	Determinations made in the usual manner. No acid present.	4.83
95	0.0084	2.00	0.78	Iodine added to the alkaloid, no acid present. Solution shaken several minutes, filtered and titrated.	3.82
96	0.0084	2.00	0.95		
97	0.0084	2.00	0.64	Iodine added to alkaloid, then 0.25 gram H ₂ SO ₄ added.	2.37
98	0.0084	2.00	0.43		
99	0.0084	2.00	0.15		
100	0.0084	2.00	0.24	0.25 gram H ₂ SO ₄ added to alkaloid, then iodine added.	0.89

These determinations show that the effect of adding acid to the solution after the admixture of alkaloidal and iodine solutions, is merely to arrest the reaction and prevent the further formation of periodides, rather than to destroy to any considerable extent the compounds already formed. Moreover, in the experiments with free codein (numbered 73, 74, and 75) the filtrates after titration with thiosulphate were acidified with sulphuric acid and no iodine was liberated after several hours, so that the addition of acid after equilibrium has been reached would seem to be without effect.

It has been shown that morphine, codeine, and heroin are precipitated by Wagner's reagent from their aqueous solutions even when no acid, either bound or free, is present. It was now found that a solution of iodine in water, or in water to which a little acetone or alcohol had been added to increase the solubility of the halogen, would also give alkaloidal precipitates which were apparently lower periodides. A saturated solution of iodine in $\frac{N}{10}$ sulphuric acid also gave a codein periodide when added to a concentrated solution of free codeine. It is known that periodides may be formed in the absence of water by using organic solvents. Finally it will be shown that it is unnecessary even to dissolve the iodine and base, and that these alkaloids, or their salts, will combine with the vapor of iodine in the entire absence of moisture with the formation of compounds which are plainly periodides.

EXPERIMENTS WITH IODINE VAPOR.

The behavior of the alkaloids toward iodine is in general similar, whether the latter is in gaseous form or in solution. For example, morphine, codeine, and heroin, both as salts and in the free state, take up iodine readily when exposed to its vapor. Both caffeine and theobromine in the free state exhibit no affinity for iodine under similar circumstances, either in the presence or absence of moisture. On the other hand if they are exposed simultaneously to the vapors of iodine and moist hydrochloric acid they are readily converted into periodides. The experiments carried out with caffeine indicated that the periodide formed in this manner is identical with the well-known pentaiodide which is always the result of reactions in aqueous solutions.

The following table gives the results of the experiments with the free alkaloids. These were dried to constant weight, morphine and codeine at 95° and heroin in a vacuum desiccator over sulphuric acid. They were then exposed in a desiccator to the vapor of iodine.

TABLE XII.—*Absorption of iodine vapor by dry alkaloids.*

Time.	Morphine.		Codeine.		Heroin.	
	Grams iodine taken up.	Atoms iodine per molecule alkaloid.	Grams iodine taken up.	Atoms iodine per molecule alkaloid.	Grams iodine taken up.	Atoms iodine per molecule alkaloid.
6 hours -----	0.0126	0.04	0.0515	0.22	0.0185	0.10
1 day -----	0.0618	0.19	0.1813	0.76	0.0495	0.35
2 days -----	0.1362	0.42	0.3351	1.41	0.0981	0.69
3 days -----	0.2593	0.79	0.4780	2.01	0.1597	1.12
4 days -----	0.3636	1.11	0.6208	2.61	0.2265	1.61
5 days -----	0.4758	1.45	0.7755	3.26	0.3095	2.18
6 days -----	0.6171	1.88	0.9025	3.80	0.3925	2.77
7 days -----	0.6998	2.14	1.0301	4.33	0.4598	3.24
8 days -----	0.7943	2.42	1.1640	4.90	0.5188	3.66
9 days -----	0.8902	2.72	1.2708	5.35	0.5670	4.00
11 days -----	1.1386	3.48	1.4767	6.21	0.6895	4.86
12 days -----	1.2785	3.90	1.5180	6.60	0.7748	5.47
13 days -----	1.4273	4.36	1.6214	6.82	0.8371	5.90
14 days -----	1.5822	4.83	1.6700	7.03	0.8927	6.30
15 days -----	1.7212	5.25	1.7185	7.23	0.9415	6.64
16 days -----	1.8380	5.61	1.7792	7.49	0.9635	6.80
18 days -----	2.0402	6.23	1.8413	7.75	0.9874	6.97
20 days -----	2.1886	6.68	1.9136	8.05	1.0218	7.20
22 days -----	2.2836	6.97	1.9873	8.36	1.0523	7.42
24 days -----	2.3831	7.27	2.0536	8.64	1.0821	7.63
27 days -----	2.4562	7.50	2.1137	8.90	1.0985	7.75
32 days -----	2.5224	7.70	2.1875	9.20	1.1157	7.87
38 days -----	2.5666	7.83	2.2373	9.42	1.1295	7.97
44 days -----	2.5893	7.90	2.2538	9.48	1.1339	8.00
51 days -----	2.5983	7.93	2.2553	9.49	1.1395	8.04
61 days -----	2.5985	7.93	2.2379	9.42		
68 days -----			2.2305	9.39	1.1395	8.04
75 days -----			2.1730	9.15	1.0941	7.71
99 days -----			2.1822	9.18	1.1544	8.14
133 days -----			2.1477	9.04	1.1718	8.27
200 days -----			2.1075	8.47	1.1709	8.26

A graphic presentation of the data for the first thirty-eight days is given in the curves of figure 3.

It was discovered that the vapor of iodine had attacked the pans of the balance, disturbing the equilibrium to the extent of slightly more than three milligrams, so that a minus correction of 0.0033 gram should be applied to the weight recorded at the end of the experiments.

After fifty-one days, equilibrium had apparently been reached, and at this point the corrected weights give the following ratios: Morphine, 7.92 atoms of iodine per molecule of alkaloid; codeine, 9.47; and heroin, 8.02. The morphine periodide was then removed for a purpose referred to later and the others left for further investigation. Instead of showing further gain in weight, heroin remained constant, while codeine

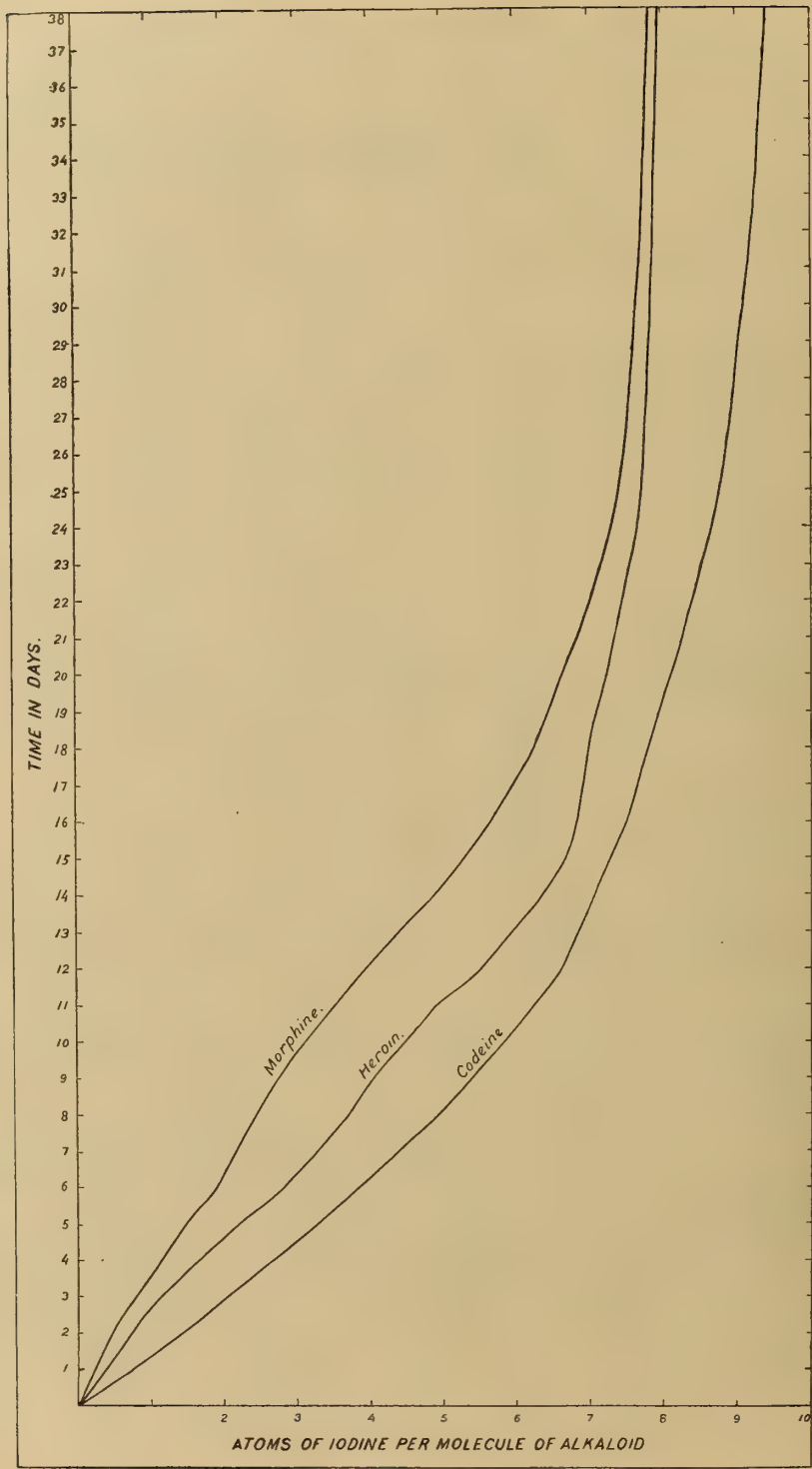


FIG. 3.

began to lose. Since it was thought that this loss might be due to the change in the equilibrium of iodine and alkaloid brought about by the warm weather encountered at that time the desiccator was placed for a week in cold storage. However, the result was a noticeable loss of iodine in each periodide. Further exposure had little effect, although codeine lost and heroin gained a small amount of iodine. It is believed that the anomalies noted result from some molecular changes which occur after long exposure. The periodides were found to be less soluble in alcohol than those freshly precipitated from aqueous solution, and the alcoholic solution, instead of having a deep red color, had a brown and in one case a green tint.

It is not possible to draw any conclusions as to the relative affinity of the different alkaloids for iodine from these experiments. Different amounts of alkaloid were taken and the amount of surface exposed and the degree of subdivision also were not the same. Probably the morphine crystals were the coarsest and those of codeine the finest. The weight of morphine taken was 0.7359 gram, of codeine 0.5598 gram, and of heroin 0.4112 gram.

The morphine periodide was placed in a second desiccator with some fresh morphine to ascertain if an equilibrium would be established. This experiment gave the following result:

TABLE XIII.—*Equilibrium between morphine, periodide, and morphine.*

Time in days.	Morphine periodide.			Morphine.		
	Weight of morphine.	Weight of iodine.	Atoms iodine per molecule of alkaloid.	Weight of morphine.	Weight of iodine.	Atoms iodine per molecule of alkaloid.
	Gram.	Gram.		Gram.	Gram.	
-----	0.7359	2.5985	7.93	0.7221	0.0000	0.00
6	0.7359	2.1208	6.47	0.7221	0.8004	2.57
13	0.7359	1.9426	5.93	0.7221	1.0436	3.36
21	0.7359	1.8242	5.57	0.7221	1.2039	3.87
38	0.7359	1.7100	5.22	0.7221	1.3484	4.34
72	0.7359	1.6124	4.92	0.7221	1.4319	4.60
86	0.7359	1.5903	^a 4.85	0.7221	1.4389	4.63

^a Corrected=4.64. The fact that the fresh morphine gained more iodine than the periodide lost is attributed to their having been placed in a desiccator previously saturated with iodine.

A series of experiments was also made with the sulphates of the alkaloids. The work with heroin sulphate is not included in the following table, inasmuch as there is reason to believe that the salt contained a small amount of free heroin. The weight of morphine sulphate was 0.1192 gram, that of codeine sulphate 0.2133 gram; each was thoroughly dried at 95° and introduced in an anhydrous condition.

TABLE XIV.—*Action of iodine vapor in the sulphate of morphine and codeine.*

Time in days.	Morphine sulphate.		Codeine sulphate.	
	Gain in weight.	Atoms of iodine per molecule alkaloid.	Gain in weight.	Atoms of iodine per molecule alkaloid.
	<i>Gram.</i>		<i>Gram.</i>	
1	0.0019	0.048	0.0061	0.09
2	0.0026	0.065	0.0101	0.15
3	0.0033	0.083	0.0178	0.26
4			0.0272	0.40
5	0.0049	0.12	0.0353	0.51
7	0.0061	0.15	0.0520	0.75
10	0.0081	0.20	0.0962	1.40
27	0.0321	0.80	0.3288	4.78
39	0.0676	1.69	0.5133	7.47
87	0.1706	4.27	0.5350	7.78
121	0.2030	5.08	0.5096	7.42
*144	0.2079	5.21	0.5006	7.28

* These results also are somewhat high, since no correction has been applied for the change in the equilibrium of the balance during the experiments.

The sample of heroin sulphate referred to above took up iodine very much faster than either of the other sulphates, and it seems very probable that pure heroin sulphate would absorb iodine more rapidly than the sulphates of the other alkaloids. Codeine sulphate has certainly a greater affinity for iodine than has morphine sulphate.

It is obvious also upon comparison of the results obtained with the free bases and with their salts that the free bases have a greater affinity for iodine than their salts, absorbing iodine to a greater degree and with considerably greater rapidity. The introduction of the acid group has a marked effect in diminishing the reactivity of the compound with iodine. It will be remembered that the same effect was observed in aqueous solutions and indeed the reactions observed in the desiccators appear to be parallel with them. The color of the periodide became darker in every case as more iodine was absorbed and the final product was always a black, pitchy or tar-like compound.

CONCLUSIONS.

It has been shown that the alkaloids morphine, codeine, and heroin, as well as their salts, have a remarkable affinity for iodine, the combination occurring under a wide range of circumstances whenever the reacting substances are brought together.

Iodine will combine with these alkaloids in the absence of any solvent, in solutions of organic solvents and in aqueous solutions, whether the

solution be one containing free mineral acid and alkaloid, neutral alkaloidal salt or free alkaloid and whether potassium iodide is present or absent.

Neither in aqueous solution nor in the absence of solvent is there any marked tendency toward the formation of a definite compound or compounds; on the other hand the reaction is apparently dependent on the relative concentration of iodine, and the phenomena observed are essentially those of equilibrium involving questions of vapor and osmotic pressure.

Moreover, it has been shown that it is not possible to recover with thiosulphate the entire amount of "free" iodine which has combined with the alkaloid. In the case of these alkaloids, therefore, and probably many other alkaloids as well, it is believed that the periodides formed in aqueous solution differ both in mode of formation and in constitution from the comparatively simple compounds demanded by the commonly accepted theory of periodides.

At present no theory is advanced concerning the constitution of these various compounds and the mechanism of their formation, but an investigation of this question will be undertaken when an opportunity is presented.

ILLUSTRATIONS.

TEXT FIGURES.

- FIG. 1. The formation of periodides of morphine, codeine, and heroin in acid solution.
2. The formation of periodides of morphine, codeine, and heroin in acid solution.
3. The absorbtion of gaseous iodine by morphine, codeine, and heroin.

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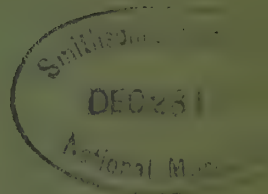
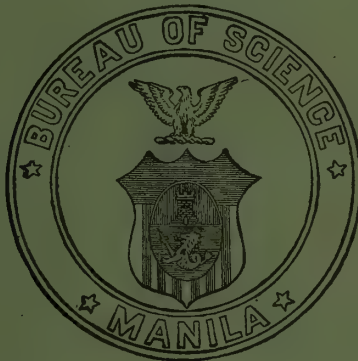
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PHILIPPINE SOILS AND SOME OF THE FACTORS WHICH INFLUENCE THEM.

By ALVIN J. COX.

*(From the Laboratory of General, Inorganic and Physical Chemistry, Bureau of
Science, Manila, P. I.)*

The soil, or that part of the land surface of the earth in condition to support and grow plants, is a heterogeneous system of solid, liquid, and gaseous components which react on each other. These reactions are extremely important and, although they have been extensively studied, they are so complicated that much remains to be discovered. In this paper I desire to deal only with the first-named component, its constitution, and some of the factors which influence the soil. An examination of any soil shows that its solid phase is composed of two parts, the inorganic constituents or the fine earthy material, and more or less organic matter. It is very rare for a natural soil to consist of inorganic matter alone, in fact when it ceases to contain organic matter it ceases to be a soil at all and is simply a mass of pure or mixed silt, sand, or clay.

The inorganic fraction of the soil consists of sand grains, silt, and clay of various degrees of fineness, resulting from the previous decomposition and disintegration of rocks. A large part is still in the mineral condition in which it was originally derived from the parent rock. This may be shown by an examination of the large, practically insoluble residue remaining after the colored compounds of iron and other weathered portions have been dissolved by the action of hydrochloric acid. It is probably only that portion soluble in water, or in the soil-moisture which contains, besides soluble salts, carbon dioxide and other organic compounds derived from the decomposition of vegetable matter, from which the chief inorganic elements of plant food, namely, nitrogen, phosphorus,

potassium and calcium are derived. It is fortunate that the inorganic constituents are not in a constant state of combination but rather are distributed between the soil-moisture and the undissolved substance in contact with the solution in a state of equilibrium according to known laws, else the plant food would soon be exhausted. When a portion of the inorganic constituents is withdrawn from the soil-moisture by the growing plant, more soluble salts from the soil begin to go into solution and finally when the soluble salts approach exhaustion, probably more begin to form from the practically insoluble ones. However, it is not my intention to discuss further the exceedingly interesting question of how these go into solution or how the mineral plant-food supply is maintained.

The organic fraction of the soil, which is the source of a part of the food of plants, may consist of almost any kind of animal or plant remains and the products of their degradation and decomposition, and is usually the result of the growth, degradation, and decomposition of organisms and vegetable matter on the surface of the ground or of animal matter (manure) artificially supplied. A part of the organic matter often markedly shows the original plant fiber, while the other portion no longer retains any of the original structure but has become a black, characteristic product, called humus, which surrounds the soil particles. Soils which contain a large quantity of humus are usually dark in color, but organic matter does not always impart a black color and black soils are not necessarily high in organic matter, the color being determined rather by the soil particles themselves.

The suitability and the maintenance of the productive capacity of soils has been a subject of the greatest concern and interest from the earliest historic times. In the United States the study of soils adapted to the various crops has been taken up very carefully. Extensive studies have been made by the Bureau of Soils of the United States Department of Agriculture, and others, of the soils suitable for the production of the great cereal crops, of the cotton soils of the Gulf States, of the rice soils of Arkansas and Louisiana and of those suitable for sugar, tobacco, fruit, etc. The Bureau of Science has already published a considerable number of data on the soils suitable for the growing of sugar in the Philippines,¹ but very few have been segregated concerning those best adapted for the cultivation of rice, both mountain and lowland, coconuts, hemp, coffee, pineapples, sweet potatoes, peanuts, and other crops of the Archipelago. Some of these products, like coconuts and hemp, reach the highest development only on certain kinds of soils, and in time we hope to establish the type.²

¹ Walker, H. S., *The Sugar Industry in the Island of Negros*, Department of the Interior, Bureau of Science, Manila, 1910.

² Copeland, *This Journal* (1906), 1, 6, shows that a considerable supply of water must constantly be at the disposal of the coconut, or it will protect itself against injurious desiccation by a partial suspension of its vitality; and Walker, *ibid.*, 60, shows that in view of the large amount of water necessary to the life of coconut trees they grow better in very porous sandy soil rather than in one from which water and soluble nutriment can only be taken up with difficulty.

Such natural agencies as the mean, maximum, and minimum temperature and the temperature under the surface of the ground, the amount of light and sunshine, winds and the evaporation of the soil moisture, exposure, altitude, humidity, the amount and distribution of the rainfall and other climatic and physical conditions exert an influence either favorably or unfavorably and are of as great importance in the production and quality of crops as the inherent characteristics of the soil itself. It is more clearly recognized now than ever before that there is not only one factor, but a summation of a number of factors which influence the soil and that a most intelligent and thorough understanding and systematization of all of these is necessary to obtain the best results, for at a given time any one of these may become a limiting factor. Even in the older districts in the Philippines no exact records of some of the factors enumerated above have been kept; neither is there much information as to the character or crops that can be grown profitably. It will be many years before these can be made a matter of careful record and the statistics for a given area presented in a definite form. With a knowledge of either the climatic conditions or the character of crops that can be grown the other may be interpreted within certain limits and the use which can be made of the soil approximated.

In the Philippines many of the climatic conditions are approximately constant, as is shown by the following numbers which I have tabulated from the reports of the Philippine Weather Bureau.

TABLE I.—*Mean shade temperature 1904-9.*

[Numbers give degrees and are the average of several daily observations.]

Station, province, island.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Vigan, Ilocos Sur, Luzon	25.9	25.7	27.1	28.4	28.7	27.7	27.0	26.9	27.1	27.6	26.9	26.2	27.1
Dagupan, Pangasinan, Luzon	25.7	25.8	27.2	27.5	28.3	27.8	26.9	26.9	27.0	27.2	26.3	25.7	26.9
San Isidro, Nueva Ecija, Luzon	24.7	25.2	26.7	28.5	28.3	27.3	26.4	26.4	26.4	26.5	25.5	25.2	26.4
Olongapo, Zambales, Luzon	25.6	25.8	26.8	28.1	27.6	27.1	28.3	26.4	26.1	26.6	26.1	25.7	26.7
Manila, Luzon	25.0	25.3	26.8	28.3	28.6	28.0	27.2	27.1	27.0	26.9	26.0	25.2	26.8
Iloilo, Iloilo, Panay	25.5	25.6	26.6	27.9	27.9	27.1	26.5	26.6	26.3	26.5	26.1	25.8	26.5
Santo Domingo, Batanes Islands, Batan	22.4	22.6	23.8	26.8	28.3	28.8	28.9	28.9	28.2	27.5	25.2	23.4	26.2
Aparri, Cagayan, Luzon	23.3	23.4	24.8	26.6	27.4	27.9	27.6	27.5	27.2	26.5	25.0	23.6	25.9
Atimonan, Tayabas, Luzon	25.4	25.6	26.6	28.0	28.5	27.9	27.5	27.5	27.0	27.1	26.3	26.1	26.9
Legaspi, Albay, Luzon	25.6	25.6	26.5	27.4	27.9	27.5	26.1	27.3	26.9	27.1	26.4	26.2	26.7
Capiz, Capiz, Panay	25.7	25.8	26.4	27.6	27.1	27.6	27.0	27.0	26.9	26.8	26.4	26.2	26.7
Tacloban, Leyte, Leyte	25.7	25.6	26.3	27.4	28.0	27.5	27.4	27.5	27.3	27.2	26.5	26.1	26.9
Ormoc, Leyte, Leyte	24.9	24.8	25.5	26.1	26.6	26.4	26.3	26.8	26.1	25.9	25.4	25.2	25.6
Cebu, Cebu, Cebu	25.9	25.9	27.2	27.6	28.1	27.6	27.0	27.1	26.8	26.8	26.4	26.2	26.9
Tagbilaran, Bohol, Bohol	25.9	25.9	26.5	27.3	28.0	27.6	27.4	27.4	27.4	27.2	26.7	26.3	27.0
Surigao, Surigao, Mindanao	25.7	25.6	26.0	26.8	27.4	27.6	27.4	27.4	27.3	27.2	26.4	25.7	26.7

* Normal, 1885-1907, *Annual Rept. Dir. P. I. Weath. Bur.* (1907), 151.

TABLE II.—*Absolute maximum temperature 1904-9.*

Station.	January.		February.		March.		April.		May.		June.		July.		August.		September.		October.		November.		December.		Period.	
	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Mo.	°C.
Vigan, Ilocos Sur	1904	35.2	1908	34.9	1905	36.3	1905	38.7	1905	37.9	1905	37.4	1904	34.9	1905	35.2	1905	36.1	1904	37.5	1904	34.9	1904	35.0	Apr.	38.7
Dagupan, Pangasinan	1909	35.0	1906	36.7	1907	38.5	1908	39.0	1906	39.5	1908	38.7	1908	36.7	1906	36.4	1908	35.9	1904	36.2	1908	35.4	1908	34.8	May	39.5
San Isidro, Nueva Ecija	1905	35.5	1906	37.8	1906	38.3	1905	39.5	1906	40.9	1909	37.9	1907	36.4	1906	36.0	1906	35.7	1906	35.8	1907	34.5	1905	36.4	May	40.9
Olongapo, Zambales	1905	35.0	1908	35.0	1906	37.4	1906	37.6	1909	36.6	1905	37.3	1905	33.6	1906	35.7	1908	34.7	1907	34.5	1907	35.2	1907	34.4	Apr.	37.6
Manila	1905	33.6	1906	35.6	1906	36.1	1905	37.7	1906	37.6	1909	36.9	1906	33.6	1909	34.2	1905	33.7	1907	33.7	1907	33.9	1905	33.2	Apr.	37.7
Iloilo, Iloilo	1905	33.1	1906	33.2	1905	35.0	1905	35.9	1905	35.4	1906	35.5	1906	33.5	1909	34.4	1909	33.9	1907	33.6	1908	33.0	1908	32.4	Apr.	35.9
Santo Domingo, Batanes Islands	1906	29.3	1906	30.5	1906	31.1	1906	32.1	1906	33.6	1906	33.9	1906	34.3	1906	33.6	1906	32.9	1907	31.9	1909	31.4	1905	30.2	July	34.3
Aparri, Cagayan	1905	31.8	1906	33.9	1905	35.0	1905	35.3	1909	35.5	1905	36.0	1906	36.0	1906	35.0	1909	34.2	1907	33.1	1909	32.5	1909	31.0	June	36.0
Atimonan, Tayabas	1909	33.5	1906	34.5	1905	35.8	1907	36.6	1907	36.9	1907	36.7	1906	35.1	1909	36.0	1908	35.9	1905	35.0	1906	33.9	1908	32.5	May	36.9
Legaspi, Albay	1909	32.1	1906	33.3	1906	33.4	1906	35.5	1907	36.5	1907	35.6	1906	35.3	1909	35.8	1908	36.0	1906	35.1	1906	34.1	1905	32.8	May	36.5
Capiz, Capiz	1905	30.8	1906	31.7	1904	32.8	1904	35.1	1904	34.8	1904	36.1	1906	35.1	1909	33.6	1906	33.6	1909	34.2	1907	32.0	1908	30.2	June	36.1
Tacloban, Leyte	1906	33.0	1906	34.4	1904	34.7	1907	36.0	1905	36.1	1904	36.0	1904	35.1	1907	35.7	1905	35.8	1908	34.6	1906	34.5	1904	32.5	May	36.1
Ormoc, Leyte	1906	22.6	1906	33.1	1906	33.8	1905	34.5	1906	34.1	1909	34.1	1907	33.0	1909	32.5	1907	32.9	1909	33.2	1907	33.7	1906	32.5	Apr.	34.5
Cebu, Cebu	1905	31.6	1906	31.4	1908	31.9	1905	33.5	1904	34.3	1905	34.0	1905	33.0	1907	32.5	1908	32.9	1907	32.8	1905	32.0	1909	31.2	May	34.3
Maasin, Leyte	1909	31.0	1906	31.6	1905	33.1	1905	33.9	1905	33.8	1907	34.2	1907	34.0	1906	32.7	1906	32.9	1907	33.0	1907	32.4	1906	31.5	June	34.2
Tagbilaran, Bohol	1905	33.0	1906	33.0	1905	34.1	1905	35.2	1906	36.2	1906	35.1	1905	34.6	1908	34.3	1907	35.5	1905	35.5	1905	34.0	1906	32.7	May	36.2
Surigao, Surigao	1906	33.4	1906	36.5	1907	33.5	1906	35.5	1906	34.5	1905	35.5	1907	35.3	1906	36.0	1906	35.2	1905	35.6	1905	34.5	1905	34.6	Feb.	36.5

TABLE III.—*Absolute minimum temperature 1901-9.*

Station	January.		February.		March.		April.		May.		June.		July.		August.		Septem-ber.		October.		Novem-ber.		Decem-ber.		Period.	
	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Year	°C.	Mo.	°C.
Vigan, Ilocos Sur.....	1905	17.4	1904	16.0	1905	18.5	1905	19.4	1904	20.7	1905	20.0	1904	20.5	1905	19.3	1905	18.5	1904	20.7	1905	16.6	1904	15.3	Dec.	15.3
Dagupan, Pangasinan.....	1907	14.3	1905	17.3	1909	18.3	1905	21.0	1909	21.1	1904	21.5	1908	21.7	1904	21.6	1904	21.2	1906	21.4	1905	17.2	1904	16.5	Jan.	14.3
San Isidro, Nueva Ecija.....	1905	13.0	1905	12.9	1904	13.3	1904	16.6	1906	18.0	1906	18.8	1906	18.9	1906	18.5	1906	18.2	1906	17.0	1905	13.5	1904	12.5	Dec.	12.5
Olongapo, Zambales.....	1905	12.5	1905	13.4	1904	16.6	1904	17.2	1901	17.1	1904	18.5	1904	19.0	1904	20.1	1904	19.9	1904	18.2	1904	14.4	1904	12.3	Dec.	12.3
Manila.....	1907	15.0	1905	16.0	1904	17.2	1907	19.1	1906	20.4	1905	22.0	1904	21.6	1906	21.2	1906	21.6	1908	20.2	1905	17.5	1904	15.9	Jan.	15.0
Iloilo, Iloilo.....	1905	18.5	1905	18.0	1904	19.3	1907	21.2	1908	21.9	1904	17.9	1904	20.1	1904	20.1	1904	20.1	1907	21.0	1906	20.5	1904	18.3	Feb.	18.0
Santo Domingo, Batanes Is-lands.....	1904	15.1	1904	15.2	1906	16.0	1907	17.6	1904	19.7	1907	21.5	1904	20.4	1907	21.2	1904	20.0	1907	20.7	1908	18.7	1909	17.2	Feb.	15.1
Aparri, Cagayan.....	1904	17.0	1905	15.5	1905	15.8	1904	18.0	1901	20.0	1904	21.5	1906	21.2	1904	21.8	1909	21.7	1906	20.5	1905	17.0	1904	16.4	Feb.	15.5
Atimonan, Tayabas.....	1907	19.0	1905	17.7	1905	18.5	1906	20.3	1908	22.0	1904	22.0	1901	20.5	1907	21.6	1904	21.8	1907	19.9	1906	19.1	1904	18.5	Feb.	17.7
Legaspi, Albay.....	1905	17.4	1905	16.9	1905	17.5	1905	20.1	1907	20.5	1904	21.5	1907	20.8	1905	21.6	1905	21.3	1904	21.0	1904	19.3	1904	17.9	Feb.	16.9
Capiz, Capiz.....	1905	16.4	1905	18.0	1905	18.6	1907	19.6	1908	20.2	1908	20.2	1908	19.9	1907	19.0	1908	18.5	1906	20.8	1906	18.5	1904	17.5	Jan.	16.4
Tacloban, Leyte.....	1905	18.8	1905	18.4	1905	18.0	1909	21.9	1905	22.5	1908	22.0	1905	22.3	1905	20.9	1905	22.0	1904	21.9	1904	20.0	1904	17.5	Dec.	17.5
Ormoc, Leyte.....	1905	13.3	1905	15.2	1905	15.8	1907	18.2	1909	19.7	1909	20.5	1908	20.7	1905	20.7	1908	20.6	1907	19.0	1906	17.7	1904	15.8	Jan.	13.3
Cebu, Cebu.....	1905	18.9	1905	18.3	1905	19.4	1907	21.0	1905	22.5	1907	22.5	1906	21.5	1907	21.3	1905	20.9	1907	20.7	1905	20.2	1904	19.9	Feb.	18.3
Muasín, Leyte.....	1905	19.3	1905	18.0	1905	18.0	1907	20.0	1906	22.0	1906	22.0	1909	21.0	1909	21.8	1905	21.7	1908	21.0	1905	19.5	1904	19.5	Feb.	18.0
Tagbilaran, Bohol.....	1905	19.5	1905	17.9	1905	18.9	1907	21.1	1904	22.3	1907	22.0	1908	21.6	1905	21.5	1905	21.6	1905	21.8	1906	21.0	1904	20.5	Feb.	17.9
Surigao, Surigao.....	1907	18.8	1905	18.2	1905	19.1	1908	21.0	1905	21.5	1907	21.0	1906	21.7	1909	21.5	1905	21.7	1906	20.5	1905	20.5	1904	19.4	Feb.	18.2

The above tables show that the mean temperature in the Philippines is very uniform, that the maximum and minimum temperatures are not extreme and that the absolute maximum respectively minimum occurs at approximately the same time of year for all points. The temperature underground always fluctuates less than the daily extreme, therefore, in the comparison of one region with another the temperature usually drops out of consideration.

There is probably no place in the whole Archipelago where vegetation gets an insufficient supply of light and sunshine. The average minimum duration of sunshine in Manila for the years 1890-1907 is 140 hours in the month of August. The normal for 1890-1907 is shown by the following curve:

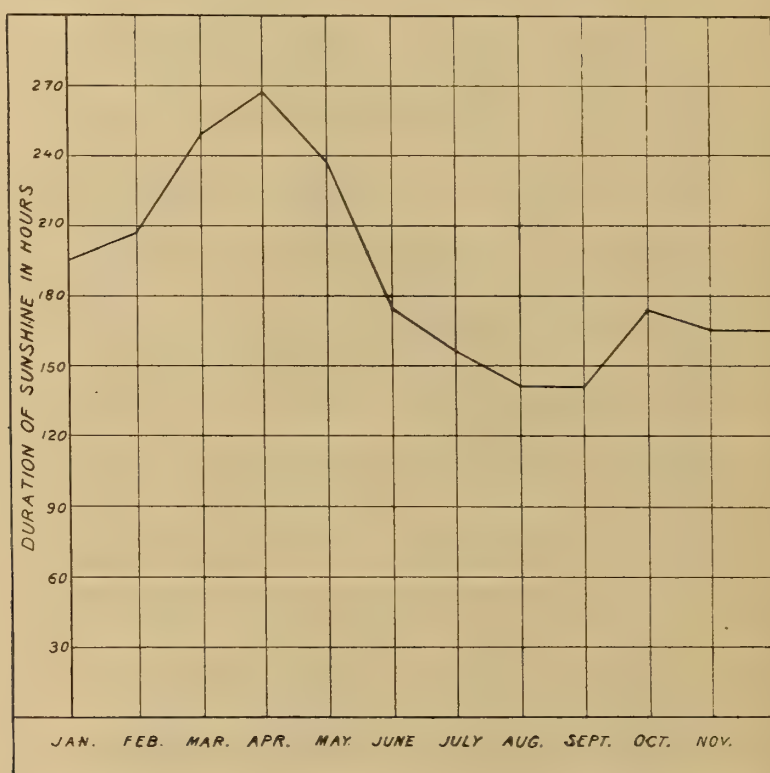


FIG. 1.—Normal duration of sunshine in Manila, 1890-1907.³

The amount of wind in general is of great importance, indirectly on account of its drying action on the soil and the hastening of transpiration, and directly when violent on account of the destruction of the plants themselves. All of these effects are the more pronounced the higher

³ From numbers, *Annual Rept. Dir. P. I. Weath. Bur.* (1907), 151.

the plants grow or the more exposed the location; on the other hand, the greater the normal humidity the less the drying action.

In the Philippines the average force of the wind is not high and will scarcely influence ordinary crops. Typhoons often do a considerable amount of damage, but it is comparatively seldom that a true typhoon strikes the Philippine Archipelago. Of much graver consideration is the question of the influence of winds on the growing of crops, for example rubber, which are introduced from the absolutely still, tropical forest. The rubber tree is extremely brittle and a small amount of wind will often injure it enough to set it back considerably in its development. The Weather Bureau reports are not sufficiently complete to warrant any special study of winds, but I recommend that prospective planters pay attention to this feature.

Evaporation measurements which are comparable with evaporation from the soil show that evaporation is approximately in proportion to the duration of the sunshine and is inversely proportional to the cloudy days and rainfall, although it is somewhat influenced by the slightly increased temperature during the summer months, as shown by the following curve.

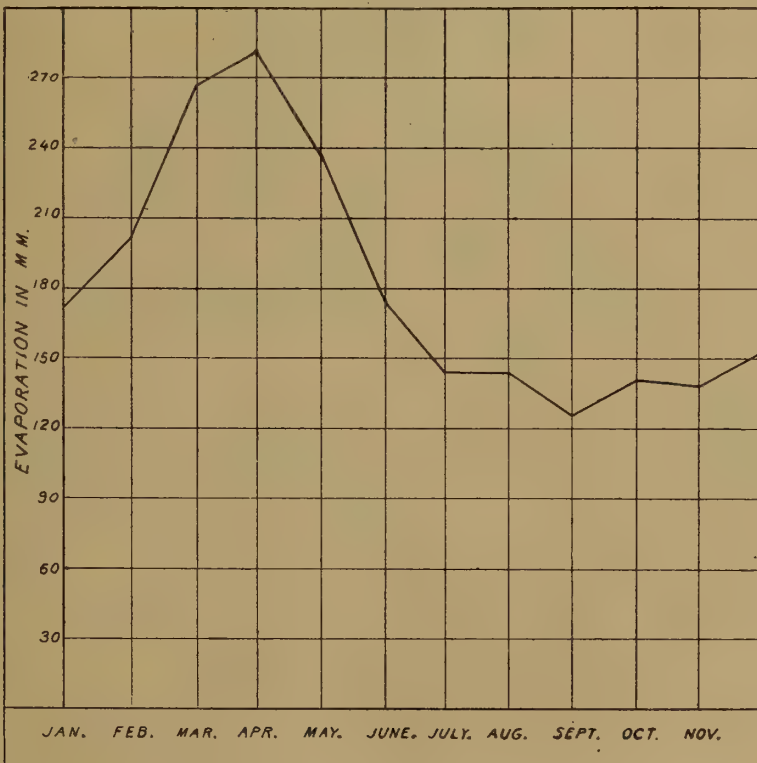


FIG. 2.—Normal evaporation 1885-1907, Manila.⁴

⁴ From numbers, *Ann. Rept. Dir. P. I. Weather Bur.* (1907), 152.



FIG. 3.—Map showing two definite types of rainfall in the Philippines.

No data are at hand from other places in the Islands, but it is believed that were they available these two factors would be shown to maintain approximately the same ratio.

There remains for consideration in the climatic conditions of the Philippines the important factors of rainfall and humidity. The value of the former is given in Tables IV and V.

In Table IV I have segregated all those weather stations which have a distribution of rainfall similar to that of Manila and in Table V those which have a rainfall more or less uniformly distributed throughout the year. These two tables conclusively show well marked wet and dry seasons for the stations named in Table IV and the absence of such variation in Table V. In the two tables are included records of practically all the stations of the Philippine Weather Bureau.⁵ When these stations are located on a map, a straight line drawn lengthwise through the Mountain Province to Laguna de Bay and thence to Iloilo exactly divides the stations given in Table IV from those given in Table V as shown in Fig. 3.⁶

⁵ I have omitted only those from which the data were so incomplete as to be of no value.

⁶ I know of no record of precipitation of measurements made in Palawan. Records of the rainfall in Borneo are not complete, but for the years 1909-10 I have collected the following:

Rainfall in Borneo, 1909 and 1910.

[Numbers represent millimeters.]

Station and elevation (meters).		Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
		Rainfall in the State of North Borneo, 1909. ^a											
Kotabelud	30			108	114	245	253	39	234	48	115	127	147
Kudat	15	971	389	148	115	255	293	384	292	128	498	510	794
Tawao	0	53	95	52	13	150	148	238	118	139	330	185	204
		Average rainfall in Sarawak, 1909-10.											
Lawas	0	210	497	288	^b 426	270	303	230	^b 476	381	501	435	300
Limbang ^c	0	253	290	275	288		334	398	468	294	312	230	279
Baram ^c	20	248		228			410	236	183	^b 230	223		^d 194
Sadong Mines ^c	10	351	298	212		229	258	262	286	283	341	480	514
Sarawak Museum	15	416	567	218	298	260	251	181	292	318	273	380	465
Goebilt ^c	0	711	506	129	484	248	293	182	223	312	379		^e 760
Matang Reservoir	400	^c 788	^c 651	^c 257	^c 320	^c 362	321	113	318	348	312	318	572
Sungei Tengak Estate	0	446	527	289	316	303	237	183	292	276	324	324	450
Bau	50	445	559	360	354	272	264	172	320	298	355	288	368
Bibi	50	461	616	411	344	287	210	189	205	264	374	341	461
Dahan Estate	60	426	^b 423	313	358	244	231	115	284	305	366	312	423
Lundu	0	405	533	149	146	232	184	87	138	120	220	229	491
Samatan ^c	0	760	704	71	40	122	79	90	134	186	154	296	721
References ^f		³⁹ / ₁₅₀ ⁴⁹ / ₁₆₀	³⁹ / ₁₇₂ ⁷¹ / ₇₀	³⁹ / ₁₉₂ ⁹⁰ / ₉₁	³⁹ / ₁₁₅ ¹¹⁷ / ₁₁₇	³⁹ / ₁₄₁ ¹³⁵ / ₁₁₂	³⁹ / ₁₆₂ ¹³⁵ / ₁₃₅	³⁹ / ₁₈₂ ¹³⁵ / ₁₃₅	³⁹ / ₂₁₄ ²⁰³ / ₂₀₃	³⁹ / ₂₂₄ ²²⁴ / ₂₂₄	³⁹ / ₂₄₇ ²⁴⁴ / ₂₄₄	³⁹ / ₂₇₁ ²⁷¹ / ₂₇₁	⁴⁰ / ₂₈ ⁴⁰ / ₂₇₃

^a State of North Borneo Official Gazette (1910), 21, 104, 178, and 181.

^b For 1909 only.

^c For 1910 only.

^d 403 millimeters in 1909.

^e 477 millimeters in 1909.

^f Sarawak Official Gazette (1909), 39; (1910), 40. Figures in *italics* give volume and the other figures give the number of the page.

The precipitation at the above stations indicates that at some places in Borneo there is a noticeable diminution of the rainfall during certain seasons though on the whole the numbers given most nearly agree with those for the eastern portion of the Philippine Archipelago. With the data at hand, it is not possible further to indicate the direction of the line which differentiates the types of rainfall in the Philippines.

TABLE IV.—*Mean monthly rainfall at Manila and other stations which have a similar distribution.*

[Numbers represent millimeters.]

Station, Province.	Period averaged.	Altitude.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
		<i>Meters.</i>													
Vigan, Ilocos Sur	{ 1887-91 1893-6 1902-96 }	22	0.3	0.1	3.6	12.2	73.4	315.3	556.1	474.1	483.0	154.8	57.3	3.6	2,134.1
Candon, Ilocos Sur	1902-6	6	0.4	5.1	1.4	13.2	204.3	502.2	564.7	474.9	459.8	168.5	73.0	7.1	2,474.6
San Fernando, Union	1902-6	12	12.8	1.8	3.7	10.1	160.6	362.8	526.6	609.8	387.2	121.1	63.6	6.5	2,266.6
Baguio, Mountain	1902-6	1,456	33.9	6.8	21.9	113.4	479.2	549.4	748.4	882.3	658.6	367.5	132.0	21.6	4,001.0
	{ 1886-92 1894-7 1902-6 }	4	1.1	6.0	10.1	26.6	101.0	419.0	619.2	562.2	517.8	161.4	42.1	9.4	2,476.5
Dagupan, Pangasinan	1902-6	4.7	7.7	14.6	17.2	57.0	317.6	439.5	534.9	391.2	108.2	159.4	80.6	13.7	2,441.6
Tarlac, Tarlac	1902-6	20	4.2	8.0	33.2	73.9	172.7	268.2	395.1	258.8	377.6	207.3	67.1	35.7	1,901.8
Masinloc, Zambales	1903-6	6	0.8	0.0	5.5	85.9	125.7	1,135.1	992.9	758.8	518.9	247.4	63.4	20.0	3,954.4
Iba, Zambales	1902-3	4.2	0.0	2.8	3.0	9.8	145.2	360.8	852.1	898.8	1,200.6	49.3	87.6	7.6	3,617.6
San Isidro, Nueva Ecija	{ 1888-97 1902-6 }	20	17.3	4.7	14.4	24.7	201.3	217.8	341.6	278.9	360.1	179.4	88.7	55.6	1,784.5
Arayat, Pampanga	1902-6	8.7	17.0	5.8	8.4	36.4	149.9	259.4	373.5	212.8	307.0	223.0	59.5	38.0	1,690.7
Porac, Pampanga	1903-6	133	10.6	6.9	31.3	64.3	292.1	310.2	646.0	311.6	356.7	225.6	75.6	34.5	2,365.4
Olongapo, Zambales	1902-6	4.4	6.8	0.6	1.5	53.0	294.1	619.0	764.5	657.3	523.7	168.9	48.8	28.0	3,166.2
Marilao, Bulacan	1903-6	8	11.3	6.3	8.1	48.6	154.8	360.6	545.1	372.5	280.1	183.2	59.1	73.9	2,103.1
Balanga, Bataan	1903-6	7.5	16.7	10.2	10.6	56.3	196.0	325.2	695.4	291.2	429.0	221.2	62.4	35.2	2,349.4
Manila	{ 1865-99 1900-6 }	14.2	28.0	10.1	17.3	31.0	103.1	249.2	388.8	350.0	368.6	190.5	131.6	58.3	1,926.5
Cavite, Cavite	1902-4	6	22.8	9.7	3.1	7.7	14.4	42.7	224.6	198.8	314.4	104.2	60.1	96.6	1,188.8
Restinga, Cavite	{ 1885-8 1890-5 }	14	1.6	1.2	12.2	13.5	176.5	289.0	592.8	323.9	632.1	123.5	105.9	29.3	2,308.5
Silang, Cavite	1904-6	281	33.6	14.0	7.6	41.4	117.4	348.5	330.5	314.4	303.4	91.4	97.4	35.2	1,734.8

Corregidor	1903-6	5	11.4	4.4	2.3	18.7	126.5	344.7	569.0	354.1	417.1	230.1	78.5	42.5	2,199.3
Bifang, Laguna	1903-6	7	7.5	18.0	0.0	9.0	62.1	294.0	280.2	125.2	148.6	132.1	46.0	175.3	1,298.0
Santiago, Batangas	1886-97	14	6.5	0.2	5.7	4.6	99.4	186.9	368.2	239.9	321.5	120.8	101.6	57.5	1,512.8
Mamburao, Mindoro	1896-9	4.4	3.2	2.3	9.4	29.9	271.8	595.0	327.0	485.4	323.2	48.2	23.6	3,116.0	3,116.0
Cuyo, Cuyos Island	1903-6	14	8.9	28.6	2.2	19.5	105.6	269.2	305.8	366.5	372.5	265.8	110.7	81.2	1,931.5
San Jose de Buenavista, Antique	1902-6	4	26.8	0.0	4.8	60.8	114.4	324.4	571.4	360.2	459.0	308.1	94.4	54.5	2,378.8
Iloilo, Iloilo	{ 1894-7 1902-6 }	6	50.0	27.7	25.9	51.0	172.0	209.1	549.0	327.8	280.6	261.8	125.5	115.5	2,188.9
Average			12.9	7.3	10.2	37.4	170.4	369.1	595.5	436.8	425.8	191.9	79.2	44.6	2,827.3

^a Approximately. The average of these results is represented graphically in figure 4. ^b Cf. Phil. Weather Bull. 1904, pp. 15, 49, 79, 114.

TABLE V.—*Mean monthly rainfall of Philippine Weather Bureau stations not included in Table IV.*

[Numbers represent millimeters.]

Station, Province.	Period averaged.	Altitude.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Santo Domingo, Batanes Islands	1903-6	Meters. 18.7	263.7	48.0	86.6	111.9	252.4	166.8	304.2	405.7	241.4	468.7	186.4	324.3	2,860.1
Aparri, Cagayan	{ 1886-7 1891-2 1895-6 1902-6 }	3.5	247.1	95.3	45.7	37.9	94.0	129.0	145.1	233.3	303.0	308.5	277.6	218.8	2,135.3
Tuguegarao, Cagayan	{ 1881-2 1903-6 }	33	17.7	8.1	26.4	36.0	79.8	171.6	134.0	128.4	238.4	295.2	333.1	103.9	1,572.6
Bayombong, Nueva Ecija	1886-93	253	34.8	29.5	37.6	70.0	164.1	77.2	153.0	134.5	178.0	132.9	107.3	77.3	1,186.2
Baler, Nueva Vizcaya	1902-6	7	365.9	68.9	245.7	430.3	370.4	249.6	339.5	212.8	456.1	310.1	326.4	447.9	3,823.6
San Antonio, Laguna	1904-6	^a 296	161.1	48.9	80.6	154.6	244.6	233.7	282.8	291.3	414.5	352.3	328.1	282.5	2,825.0
Tayabas, Tayabas	{ 1891-5 1897 }	179	135.1	42.2	60.2	28.8	99.3	83.8	96.6	73.9	116.5	239.0	283.2	195.4	1,449.0
Atimonan, Tayabas	{ 1886-8 1902-6 }	7	181.0	92.2	68.7	93.7	174.6	147.4	223.3	195.1	298.7	396.1	464.1	345.0	2,679.9

^a Approximately.

TABLE V.—Mean monthly rainfall of Philippine Weather Bureau stations not included in Table IV—Continued.

Station, Province.	Period, averaged.	Altitude.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
		<i>Meters.</i>													
Nueva Caceres, Ambos Camarines	1887-8 1902-6	8	105.2	57.4	54.3	120.2	76.8	178.0	194.2	155.4	268.7	199.7	225.0	183.8	1,818.7
Legaspi, Albay	1902-6	4.3	445.6	248.2	154.6	175.0	149.9	200.7	209.9	159.1	298.4	403.4	265.8	419.1	3,129.7
Albay, Albay	1891 1893-7	7	233.5	108.2	229.0	155.4	188.3	207.6	266.2	242.1	299.8	212.5	301.0	457.0	2,960.6
Gubat, Sorsogon	1903-6	6	293.1	191.9	114.5	100.9	138.6	114.0	130.3	99.5	270.2	341.6	540.7	572.9	2,908.2
Romblon, Romblon	1903-5	6	93.0	45.8	12.2	65.4	123.4	117.5	273.9	290.5	333.5	342.8	313.3	337.4	2,368.7
Palanoc, Masbate	1904-6	3	192.6	87.2	30.2	48.1	75.2	120.7	127.9	129.0	284.2	130.2	163.2	57.4	1,445.9
Calbayog, Samar	1903-6	4.1	133.4	103.5	69.3	95.7	231.4	154.6	191.4	159.4	339.0	268.6	266.6	234.7	2,247.6
Cathalogan, Samar	1904-5	6.6	256.5	210.0	33.2	128.2	99.0	129.4	85.0	182.6	256.8	218.3	200.8	155.2	1,955.0
Borongan, Samar	1903-6	10	526.5	300.7	145.6	219.5	284.3	249.7	156.2	140.7	253.8	344.8	446.9	537.2	3,666.0
Capiz, Capiz	1902-6	6	201.0	118.5	13.7	62.4	189.5	410.3	451.7	383.6	398.3	885.7	348.5	446.0	3,859.2
Tacloban, Leyte	1904-6	6	213.0	143.3	76.6	138.0	178.3	238.0	110.5	213.4	184.0	171.0	254.1	250.0	2,170.2
Ormoc, Leyte	1902-6	4.5	229.9	75.2	82.7	78.8	80.9	196.3	290.3	290.3	334.5	266.6	185.0	147.7	2,258.2
Tuburan, Cebu	1902-6	8	113.6	78.0	18.0	12.5	69.8	123.1	171.3	121.0	175.8	197.2	161.8	153.7	1,395.8
Bacolod, Occidental Negros	1903-6	7.4	86.4	48.7	10.5	29.8	117.7	234.5	379.5	329.0	281.8	275.1	199.3	228.3	2,160.6
La Carlota, Occidental Negros	1889-97	125	59.7	55.6	47.4	87.0	229.3	304.8	358.7	378.6	392.9	350.9	199.0	127.3	2,591.2
	1878														
Cebu, Cebu	1881-2 1894-5 1897 1902-6	3	110.0	43.6	60.6	31.6	99.1	180.7	173.7	148.7	176.0	181.7	123.4	160.2	1,489.3
Maasin, Leyte	1902-6	2.1	114.3	70.0	59.2	29.0	103.4	124.4	166.5	131.3	237.5	157.4	166.8	169.3	1,529.1
Tagbilaran, Bohol	1902-6	21.9	109.1	109.9	48.8	393.0	180.3	173.2	416.1	117.9	176.7	383.0	196.8	175.9	2,480.7
Surigao, Surigao	1902-6	4	289.9	280.9	189.5	305.7	176.7	55.9	145.3	77.4	145.8	222.0	332.7	416.0	2,637.8
Tandag, Surigao	1896-8	4	662.5	403.6	624.4	356.3	217.4	164.2	217.1	127.3	187.4	198.3	284.0	966.0	4,424.9
Dapitan, Zamboanga District, Moro	1902-6	6	124.8	118.5	50.1	121.0	105.8	86.2	155.5	97.5	148.8	259.3	360.7	298.3	1,926.5
Balingasac, Misamis	1902-6	7.7	70.2	57.1	3.6	27.3	47.8	229.4	239.8	169.7	314.0	225.9	253.6	86.2	1,724.6

Butuan, Butuan subprovince, Agusan---	1903-6	5	235.9	115.0	98.2	67.3	193.6	146.2	123.9	73.0	145.4	166.5	307.2	326.2	1,998.4
Caraga, Davao District, Moro-----	1902-6	30	333.4	399.4	246.6	157.5	298.9	86.4	142.7	75.7	67.4	128.4	171.9	422.6	2,460.9
Davao, Davao District, Moro-----	{ 1897-8	3	156.7	110.8	118.1	170.8	195.1	209.7	246.8	202.3	149.8	191.6	128.4	146.4	2,026.5
	{ 1902-6														
Cotabato, Cotabato District, Moro-----	1903-6	5	16.4	99.4	95.3	145.4	195.8	224.0	297.8	250.2	213.6	252.2	233.4	117.4	2,140.9
Tamontaca, Cotabato District, Moro-----	1894-6	6	61.4	50.2	128.0	82.8	191.2	312.3	224.8	200.6	293.8	136.5	151.2	76.6	1,909.4
Zamboanga, Zamboanga District, Moro.	{ 1894-6	3	25.1	38.4	25.8	42.0	88.3	109.9	112.4	80.3	88.7	96.3	125.3	77.5	905.0
	{ 1903-6														
Isabela, Basilan Island-----	1903-6	7	35.6	74.6	26.1	84.7	95.4	202.7	148.6	183.7	177.3	261.4	218.4	105.5	1,614.0
Jolo-----	{ 1894-8	7	91.2	82.3	82.7	87.5	204.8	122.4	171.6	146.2	170.6	208.8	140.4	158.8	1,666.8
	{ 1902-6														
Average ^b -----	-----	-----	184.9	117.9	105.5	120.5	158.8	175.4	212.1	184.6	245.2	266.6	250.3	261.9	2,273.7

^b The average of these results is represented graphically in figure 5.

This map shows that there are two definite and different types of rainfall in the Philippines; the western half of the Archipelago has a fairly well defined dry and wet season, and in general the eastern half has a rainfall quite equitably distributed throughout the year. The type of rainfall of the western portion of the Archipelago is shown in figure 4⁷ in which I have represented graphically the mean of the values given in Table IV. Fig. 5 presents the mean values given in Table V and shows the type of rainfall of the eastern portion of the Philippine group.

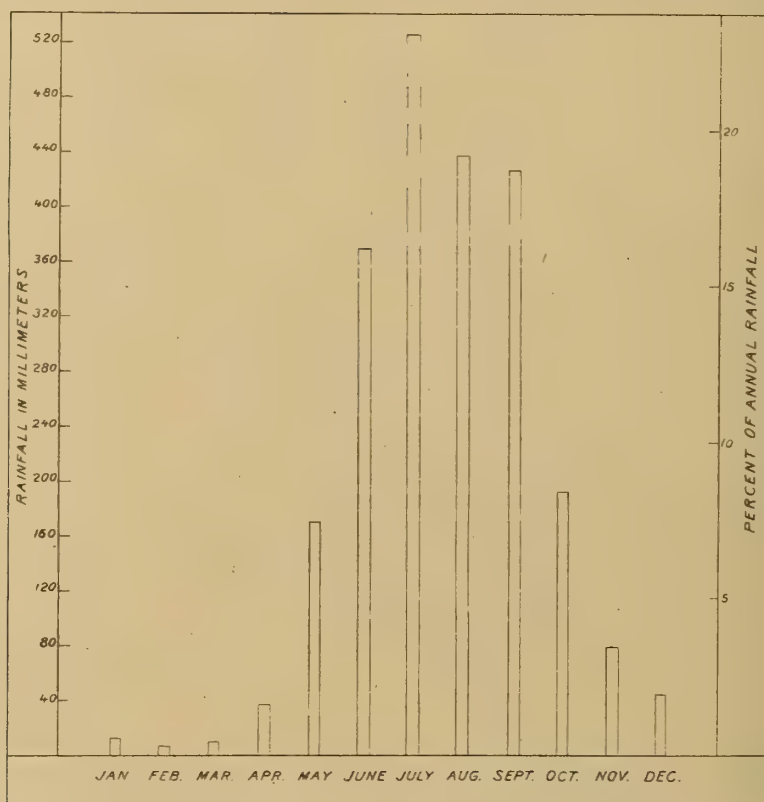


FIG. 4.—Mean rainfall in the western portion of the Philippine Archipelago.

⁷ A comparison of this with text figures 1 and 2 shows that evaporation for Manila takes place not only in proportion to the duration of the sunshine and in inverse proportion to the cloudy days, but also in inverse proportion to the rainfall, for in the Tropics cloudy days usually represent rain. No data on the evaporation in the Eastern zone are at hand, but this generality probably holds. A uniformly distributed rainfall not only controls the ground moisture by direct addition but also renders evaporation uniform.

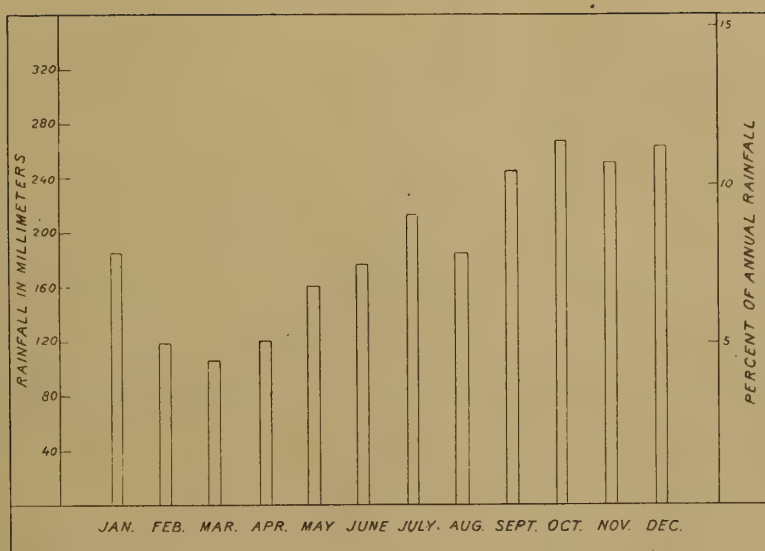


FIG. 5.—Mean rainfall in the eastern portion of the Philippine Archipelago.

This differentiation of rainfall into the eastern and western types may not be complete; for example, there is but one weather station in Mindoro and while it and probably the remainder of the lower portions of the island fall in with the western type it is believed that the rainfall in the high mountains is very heavy, due to the fact that the narrow neck of Luzon in Tayabas allows the rain clouds to pass over and precipitation to take place in the high altitudes of Mindoro. However, in general and in particular in those provinces contiguous to Manila, namely, Rizal, Bulacan, Bataan, and parts of others such as Zambales, Cavite, Batangas, and Mindoro, the dry season is very pronounced, so much so that it is impossible successfully to raise such crops as coconuts, hemp and tobacco, or others that are similarly dependent on a ground water table at an even depth, or a practically constant available water supply in the soil (chresard) which can be maintained only by a well distributed precipitation or by irrigation. Some variation is noted in the eastern part of the Islands due to the topography of the regions; some of these are somewhat differentiated into wet and dry seasons, but there is sufficient rainfall during even the driest months so as not to interfere seriously with staple crops dependent on continuous rainfall. It is sometimes stated that in certain places in the eastern part of the Archipelago the seasons are opposite to those of Manila. It is true that at a few stations in the eastern zone, for example Legaspi, Gubat, Surigao, Tandang, and Caraga, the minimum precipitation of the year is during the months from June to

September, which is the period of maximum precipitation in the western zone, but there is no definite dry and wet season; the explanation is that on account of the direction of the trade winds and the topography of the country the precipitation is much augmented during the months of October to May rather than deficient during the period from June to September, as will be recognized by the excessive annual rainfall. These facts are shown in Fig. 6 which represents graphically the results of the rainfall for Surigao given in Table V. The same inference is drawn from an examination of Table VI which gives the mean humidity by months. Surigao has a humidity for the period of November to May higher than that of any other locality; during the period from June to September which represents the maximum and the minimum respectively, the mean humidities of Manila and Surigao are almost identical. Therefore, the five stations above enumerated fall naturally into the eastern zone with uniformly distributed rainfall.

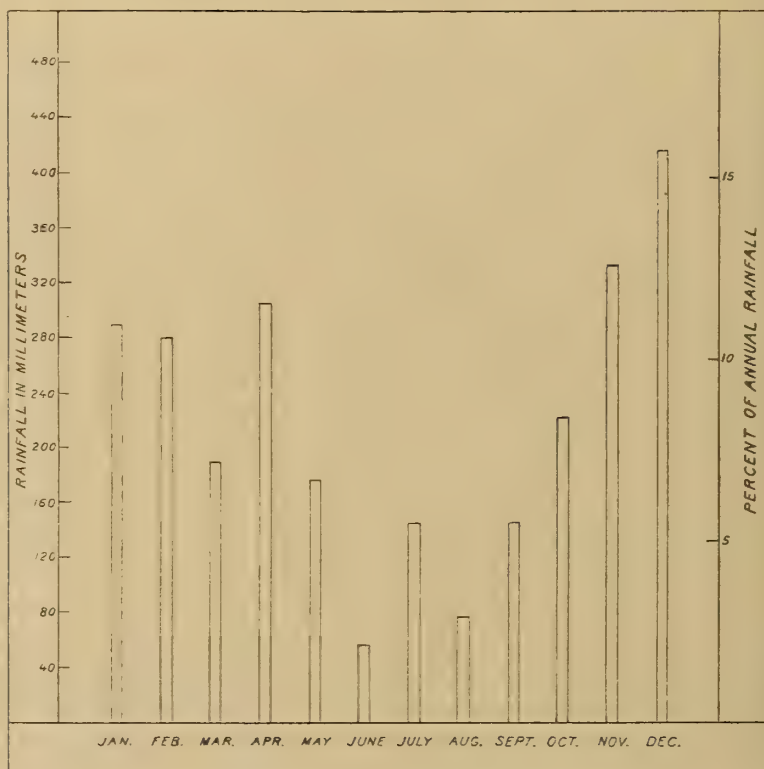


FIG. 6.—Mean rainfall in Surigao.

The humidity or the saturation deficit ($100 - \text{humidity}$) which regulates plant transpiration is only second in importance to rainfall, upon which, at the present time in most places in the Philippines the planter

must rely to maintain the soil moisture, which controls absorption. The mean humidity recorded in 16 different parts of the Archipelago is given in the following table.

TABLE VI.—*Mean humidity 1904-1909.*

[Numbers give per cent and are the average of several daily observations.]

Station, province, island.	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Average.
Vigan, Ilocos Sur, Luzon...	71.4	70.9	72.0	72.2	75.9	82.0	85.3	84.9	83.6	78.4	72.7	71.6	77.2
Dagupan, Pangasinan, Luzon	72.7	71.6	70.3	71.3	76.7	81.0	85.4	85.7	85.1	81.7	79.0	76.5	78.1
San Isidro, Nueva Ecija, Luzon	76.2	73.1	77.7	66.0	73.5	80.4	86.1	86.8	86.8	84.5	80.3	77.9	79.1
Olongapo, Zambales, Luzon	79.5	77.6	74.5	74.1	80.3	84.9	87.6	87.7	87.1	82.8	77.3	78.2	80.9
Manila, Luzon	77.7	73.7	71.8	69.8	75.8	81.1	84.6	85.0	85.7	83.5	82.5	81.1	79.3
Iloilo, Iloilo, Panay	82.3	80.1	77.2	74.0	79.3	83.6	84.8	84.3	85.1	84.4	83.4	83.9	81.9
Santo Domingo, Batanes Islands, Batan	80.1	77.8	80.7	79.8	80.9	81.4	81.6	82.1	81.3	80.2	77.4	78.1	80.1
Aparri, Cagayan, Luzon	85.6	84.4	84.0	83.6	83.9	83.9	84.4	85.0	86.2	86.5	86.1	86.0	85.0
Atimonan, Tayabas, Luzon	86.5	84.4	81.8	80.7	84.1	85.2	85.3	83.9	86.7	86.9	87.4	88.1	85.1
Legaspi, Albay, Luzon	82.0	80.2	79.7	78.2	80.1	81.3	82.0	81.4	83.3	82.5	82.9	83.2	81.4
Capiz, Capiz, Panay	87.2	85.9	87.5	82.8	87.8	86.9	87.3	87.1	88.2	88.0	86.3	87.6	86.9
Tacloban, Leyte, Leyte	82.1	80.8	77.8	77.7	78.8	81.3	81.2	78.6	80.4	81.4	82.8	84.1	80.6
Ormoc, Leyte, Leyte	81.3	79.8	76.7	76.6	80.6	83.3	83.6	83.0	84.9	85.4	84.7	83.4	82.0
Cebu, Cebu, Cebu	80.5	79.8	76.9	75.3	77.7	79.2	81.0	79.0	80.5	81.7	81.5	80.5	78.6
Tagbilaran, Bohol, Bohol	75.1	77.9	75.9	75.5	77.6	78.1	79.2	77.9	78.2	80.6	80.7	80.8	78.4
Surigao, Surigao, Mindanao	88.5	90.0	87.1	87.1	86.2	84.5	83.4	81.9	84.0	85.5	87.5	89.5	86.3

^a Normal, 1885-1907, *Annual Rept. Dir. P. I. Weath. Bur.* (1907), 150.

There is not the same marked variation in the mean humidity of the eastern and western zones, as in the rainfall, but as would be anticipated a close association of the two factors is evident. A high saturation deficit or a falling off in the mean humidity at the first five stations which belong to the western zone is to be noted during the driest months from November to May, for there are no exceedingly rainy days and the moisture in the air is practically all evaporated from the soil. For those stations which belong to the eastern zone the saturation deficit is approximately constant. Since there is less variation in humidity than in rainfall and since the former is largely dependent on the latter and is never low the discussion will be continued with reference to rainfall solely.

While the above differentiation of the rainfall of the Philippines into two types may not be absolute it is sufficiently accurate to assist in the interpretation of the factors which may influence the location of irrigation projects and the utilization of soils. With such limited data it is

not possible definitely to interpret the areas in which certain crops may be produced, yet it is possible to point out that information obtained by study and experience in either zone is applicable to other portions of the same zone and in this way interpret the region of most probable success in new districts.

The aims of agriculture in all parts of the Archipelago are practically the same, but there are many differences in crops and in agricultural practices. Perhaps these should be essentially different in the two rain zones, but in general in the same zone the best crops grown and the best methods used by any province should be extended to every other district possessing the same soil characteristics.

It is an established fact that alterations of wet and dry periods often will show correspondingly marked differences in vegetation and frequently, if not always, the prevalence of any particular type is directly correlated with the rainfall.^s

This theory is remarkably substantiated by Table VII which shows that crop distribution in the Philippines has naturally followed the lines of rainfall.

^s With many plants a dry season produces the same effect as winter.

TABLE VII.—Statistics of agriculture in the Philippine Islands.^a

Province.	Provincial area in hectares. ^b	Area in hectares, fiscal year 1909. ^c				Area in hectares, fiscal year 1910. ^d					Total cultivated area in hectares. ^f	Cultivated in coconuts, hemp, and tobacco, fiscal year 1910.	
		Ma-guey.	Coffee.	Cacao.	Rice.	Sugar.	Corn.	Coco-nuts. ^e	Hemp.	To-bacco.		Hectares.	Percent of total area.
Agusan.....	1,879,980	---	---	4	765	---	644	132	2,394	---	3,989	2,526	64.2
Albay.....	461,797	1	8	65	17,107	141	3,480	7,276	91,776	---	119,854	99,052	82.6
Ambos Camarines.....	849,261	1	10	134	24,728	887	6,922	5,966	101,600	---	139,798	107,566	76.9
Antique.....	298,706	51	23	37	31,933	1,580	4,014	672	1,009	57	39,376	1,738	4.4
Bataan.....	139,083	9	---	5	8,261	341	2,567	49	5	---	11,237	54	0.5
Batangas.....	311,059	56	26	32	33,492	5,183	13,056	474	659	97	53,075	1,230	2.3
Bohol.....	391,349	420	68	75	33,059	166	34,005	6,721	7,082	93	81,689	13,396	17.0
Bulacan.....	303,807	8	4	2	52,016	2,935	5,181	8	---	63	60,217	71	0.1
Capiz.....	1,001,398	9	---	4	21,249	281	21,997	194	26	9,614	53,484	9,834	18.4
Cavite.....	160,321	---	---	---	69,226	385	5,356	8,921	7,234	895	92,073	17,050	18.5
Cebu.....	502,201	2,681	192	365	15,036	1,198	2,119	185	1,929	20	20,521	2,134	10.4
Ilocos Norte.....	344,470	993	84	75	6,638	1,866	179,414	9,469	9,095	7,248	216,968	25,812	11.9
Ilocos Sur.....	425,278	2,560	4	65	43,170	2,338	14,457	210	---	1,438	62,765	1,648	2.6
Iloilo.....	524,993	128	33	78	39,080	3,412	27,031	328	---	563	73,043	891	1.2
Isabela.....	1,260,602	154	3	3	45,254	3,408	14,144	3,097	1,647	2,172	69,961	6,916	9.9
La Laguna.....	162,911	---	6	33	3,142	42	14,725	2	---	15,857	33,931	15,859	46.7
La Union.....	164,206	560	49	59	18,229	741	5,692	14,152	6,650	---	45,503	20,802	45.7
Leyte.....	779,072	10	29	153	44,680	1,018	5,228	489	---	6,637	58,670	7,126	12.1
Manila City.....	5,180	---	---	---	22,937	815	24,118	5,767	69,191	1,666	124,706	76,624	61.4
Mindoro.....	1,042,216	---	4	8	3,578	19	462	501	1,105	180	5,857	1,786	(1)
Misamis.....	416,975	4	12	32	6,629	34	3,484	1,471	11,466	13	23,145	12,950	56.0
Moro.....	7,151,567	412	137	55	6,182	119	3,044	11,812	16,410	21	38,192	28,243	73.9
Mountain.....	1,351,193	---	308	25	17,369	175	4,412	28	---	117	22,434	145	0.6
Nueva Ecija.....	561,771	24	18	10	90,778	527	6,092	30	---	705	98,184	735	0.7

TABLE VII.—*Statistics of Agriculture in the Philippine Islands—Continued.*

Province.	Provincial area in hectares.	Area in hectares, fiscal year 1909.				Area in hectares, fiscal year 1910.					Total cultivated area in hectares.	Cultivated in coconuts, hemp, and tobacco, fiscal year 1910.	
		Ma-guey.	Coffee.	Cacao.	Rice.	Sugar.	Corn.	Coco-nuts.	Hemp.	To-bacco.		Hectares.	Percent of total area.
Nueva Vizcaya	325,050		59	20	6,284	60	161	11			6,395	11	0.2
Occidental Negros	810,670	58	168	301	29,154	26,820	42,771	2,467	4,659	1,572	107,970	8,698	8.0
Oriental Negros	482,776	44	26	197	3,862	1,410	26,212	2,327	17,359	697	52,134	20,383	39.1
Palawan	1,356,642	5			5,292	5	433	518	1,300	4	7,557	1,822	(¹)
Pampanga	224,812	5	2	7	71,686	16,551	6,733	10	3	29	95,026	42	0.0
Pangasinan	308,987	1,305	128	191	175,703	2,794	52,161	4,006		3,212	239,500	7,218	3.0
Rizal	189,847	9	6	2	16,758	1,752	2,492	2	10		21,031	12	0.1
Samar	1,366,484	18	9	101	15,830	667	18,129	13,996	27,593	211	76,554	41,800	54.6
Sorsogon	601,916	58	17	40	16,549	398	16,861	5,925	75,091	97	115,086	81,113	70.5
Surigao	623,470	1		36	12,506	47	2,308	1,635	5,085	52	21,670	6,772	31.2
Tarlac	312,095	5	11	11	135,255	4,427	3,000	60	2		142,771	62	0.0
Tayabas	1,645,686	16	66	173	30,244	1,005	5,212	22,208	14,756	290	73,970	37,254	50.4
Zambales	550,375	201	60	15	18,510	141	678	233	1	6	19,845	240	1.2
Total	29,791,734	9,919	1,598	2,472	1,192,141	83,168	578,868	131,352	475,137	53,626	2,528,281	600,115	-----

^a I have chosen as the most satisfactory a comparison by area for then any destruction or curtailment of crops through drought or storms, or because of locusts rats or other pests or blights or failure to harvest owing to the low price or the lack of labor does not affect the results.

^b Report of the Phil. Com. (1907), 2, 449-50. Some of the provincial boundaries have been since greatly changed. I have made the noted corrections on the basis of planimeter measurements from the map of the World Book Co., adjusted so as to maintain unaltered the total area given for the Philippines.

^c Figures supplied by Mr. Wm. D. Hobart of the Bureau of Agriculture. These figures will remain practically unchanged for 1910.

^d From figures published in *Phil. Agri. Rev.* (1911), 4, June and July.

^e Estimating 250 trees per hectare.

^f This does not include the area devoted to oranges, mangoes, bananas, pineapples, *zacate*, peanuts, *camotes*, cassava, *gave*, *mongos*, etc. but this is not sufficiently large materially to affect the results.

^z Made up of the Subprovince of Bukidnon (670,510 hectares) formerly a part of the Province of Misamis and the Subprovinces of Butuan (1,209,470 hectares) formerly a part of the Province of Surigao.

^a Corrected for the transfer of the Subprovince of Apayao (490,000 hectares) to Mountain Province.

[†] Including the former Province of Romblon.

[‡] Including the former Province of Abra.

[§] Corrected for the transfer of 39,000 hectares to the Subprovince of Ifugao, Mountain Province. *Cf.* footnote, "p."

[¶] The total area under cultivation in comparison with the area of the island, over one million hectares, is so small as to make a calculation of this nature valueless. The tillable land of the island as a whole is thought to be more suited to the cultivation of rice and sugar cane than to that of coconuts and hemp. The scarcity of labor has retarded agriculture and led to the planting of crops that require the least cultivation and labor in harvesting, or allowing the land to lie idle.

^m Corrected for the transfer of territory to other provinces. *Cf.* footnote "g."

ⁿ Made up principally of the former Comandancias of Danao, Cotabato, Dapitan, Zamboanga, Basilan, Jolo, Siasi, and Tawi Tawi.

^o This is the average for the whole province and makes no provision for local differences. Along the coast north of Zamboanga there is no gauge, but the amount of rainfall is said to be very similar to that of Manila and that coconuts and hemp do not thrive well without irrigation.

^p Made up of the former Provinces of Benguet and Lepanto-Bontoc the Subprovince of Apayao (*cf.* footnote "h") and the Subprovince of Ifugao (*cf.* footnotes "k" and "q"; the boundaries are defined in Act 1876 of the Philippine Commission and Executive Order No. 46) formerly a part of the Provinces of Nueva Vizcaya and Isabela.

^q Corrected for the transfer of 180,000 hectares to the Subprovince of Ifugao, Mountain Province. *Cf.* footnote, "p."

^r Made up of Paragua and the former Comandancia of Paragua Sur.

^s Including the former Province of Masbate.

^t Including the Subprovince of Marinduque.

The numbers in the last column which express the percentage of the total area in cultivation devoted to the cultivation of coconuts, hemp and tobacco are shown graphically in Fig. 7. Attention is invited to the close similarity to Fig. 3.

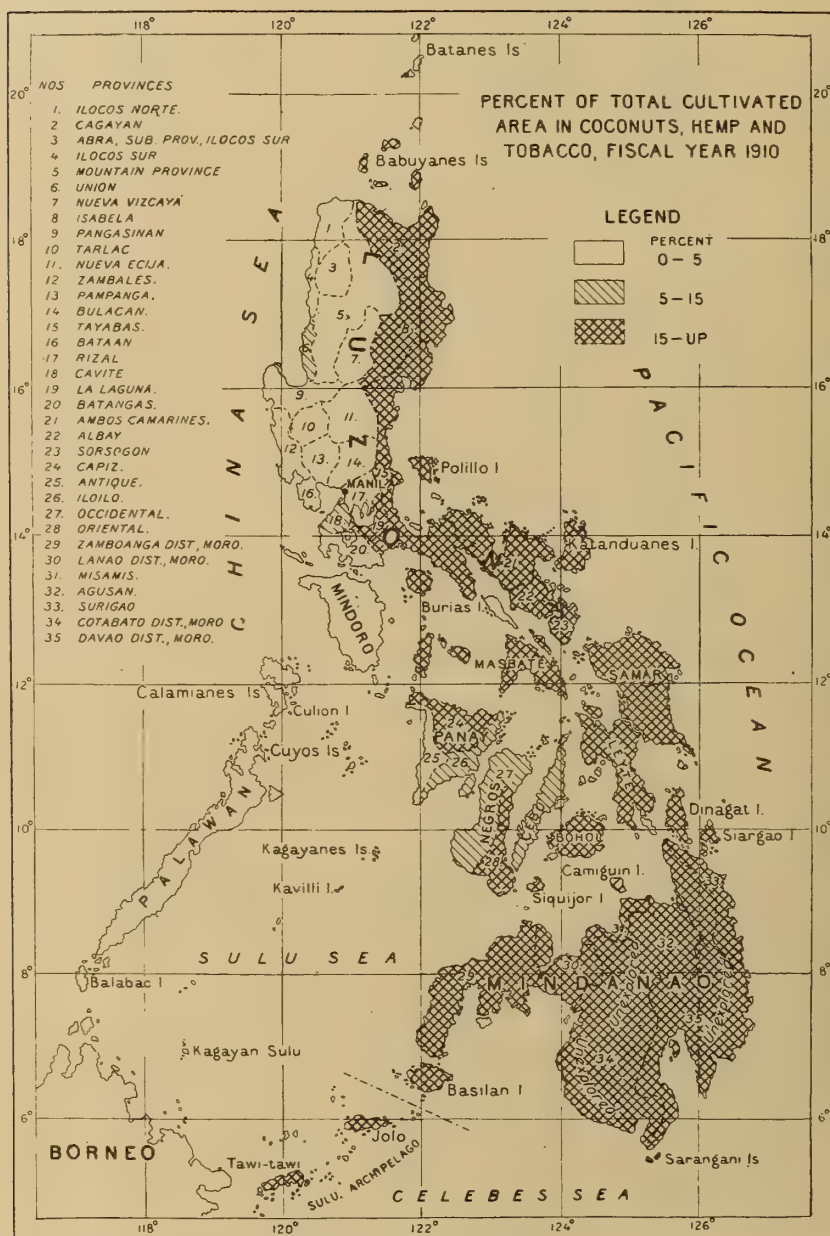


FIG. 7.—Map showing by provinces the percentage of the total area under cultivation devoted to the cultivation of coconuts, hemp, and tobacco in the Philippine Archipelago.

Not only is a rainfall well distributed throughout the year a condition absolutely essential to the success of certain crops such as hemp, coconuts, tobacco, and rubber, but this distribution also controls the prevalence of certain species of plants of the native vegetation. On the other hand, certain species of plants are adapted to a long dry season. The first striking difference in the vegetation of a region often can be referred to climatic variations. In the absence of more exact data, observation of the presence or absence of certain dominant species of plants in a given area may indicate what the local conditions are with regard to rainfall, whether abundant or scanty, but more particularly whether it is well distributed throughout the year or whether there is a long and well defined dry season and indirectly indicates the crop possibilities. A few illustrations will make this clear.

Mr. Merrill of the Bureau of Science, informs me that there are in the Philippines, as in most other countries, a number of very distinct vegetative types depending on rainfall, altitude, etc., and at low altitudes different types of vegetation are encountered which apparently owe their development largely to the equitable or interrupted distribution of rainfall throughout the year. In the regions contiguous to Manila, in Batangas, and in Mindoro it will be noticed that certain plants are to a greater or less degree dominant, good examples of which are *Bauhinia malabarica* Roxb., locally known as *alibangbang* or *calibangbang*, and *Albizia procera* Roxb., locally known as *alalangad* or *acleng parang*, these and other species found in similar habitats being apparently well adapted to a prolonged dry season. Although the above species and others characteristic of the dry regions are of wide Philippine and extra-Philippine distribution, they are not found in this Archipelago, or at least only to a very limited extent, in those regions where the rainfall is more equitably distributed; they are either not adapted to regions subject to continuous rainfall, or other more vigorous species crowd them out in the more favored localities.

In the absence of more authentic data, it seems to be safe to assume that where certain species of plants are dominant, such as those mentioned above, it is an indication that there is a prolonged dry season, and hence that such regions are not adapted to crops requiring a more equitably distributed rainfall, such as rubber, coconuts, hemp, and tobacco.

Undoubtedly, there is also a greater or less relationship between the prevalent species of any given area and the geologic formation, but unfortunately we have not at this date any correlated information, as to the prevalent species in different regions in relationship to the nature of the soil or the underlying rock.

CHEMICAL AND PHYSICAL ANALYSES OF PHILIPPINE SOILS.

However important the lines of investigation as to conditions favorable to the growth of agricultural plants and however essential the share that

the constituents of the atmosphere contribute to plant food may be, the total composition of a soil must always ultimately be taken into account, for from this under normal conditions certain elements of plant food are derived. Certain constituents become exhausted after years of cultivation and the soil requires fertilization in order to make it productive. This is especially true of the elements nitrogen and phosphorus. When the percentage of any of the elements of the plant-food existing in the soil falls below 0.1 the productive capacity of the soil may be questioned.

Such chemical and physical characteristics of Philippine soils as I have been able to segregate are given below. Although incomplete, these data should aid in the selection of suitable soil for certain crops, in the reduction of the number of individual failures, and in the future as the beginning of a basis for the study of crop yields. It is hoped that they will be of assistance to teachers in connection with their school gardens. Analyses made in the Bureau of Science of Philippine soils from many different provinces are given and as much additional information as the author has been able to secure. It must always be borne in mind that no analysis is more accurate than the sample which it represents so that the errors of sampling should be reduced to a minimum. I have prepared as an appendix to this paper directions for taking soil samples which are satisfactory and for the sake of uniformity they should be carefully followed.

CHEMICAL ANALYSES.

All analyses were made on that portion which passed a 1-millimeter screen ("fine earth"). In the case of Philippine soils, the detritus on a 1-millimeter sieve is usually very small and I believe the portion passing a sieve of this size contains practically all the constituents from which the plant derives its food and includes all that should be termed "fine earth" or soil.⁹ The methods used were substantially those of the Association of Official Agricultural Chemists.¹⁰ With the exception of moisture the results are given on the basis of a sample dried to a constant weight at 105°. In most cases the moisture was determined on the air-dried sample.¹¹ The results are as follows:

⁹ An inspection of the results of G. M. MacNider, *Journ. Ind. Eng. Chem.* (1909), 1, 447, shows that in nearly all cases the potash and in many cases the lime and nitrogen are entirely contained in the soil passing an 0.5-millimeter sieve, but that the phosphoric anhydride is more uniformly distributed. If there were to be a large detritus on a 1-millimeter sieve the results with respect to potash and in many cases to lime and nitrogen might appear high and would not fairly represent the composition of the soil.

¹⁰ *U. S. Dept. Agri., Bur. Chem. Bull. No. 107* (Revised).

¹¹ The present practice of the laboratory is to use the dry weight as the basis on which to compute the percentage of moisture also. The advantage of computing percentages on this basis is that it furnishes a constant means of comparison, whereas if computed on the actual or wet weight the basis would vary with every change in the amount of moisture.

TABLE VIII.—*Chemical analyses of Philippine soils.*

[Numbers give percentages.]

Number.	Specimen of soil.	Fine earth, water free basis.								Fine earth.	Source.	Remarks.	Number.
		Moisture. (H ₂ O),	Loss on ignition.	Nitrogen (N),	Phosphoric anhydride (P ₂ O ₅),	Lime (CaO),	Magnesia (MgO),	Potash (K ₂ O),	Soda (Na ₂ O),	Humus.	Soil acidity (per cent Ca CO ₃). ^a		
1	Brown surface.	4.86	11.79	0.138	0.059	0.35	None.	0.05	—	—	—	Santa Cruz, Cagayan.	1
2	Dark surface.	1.98	8.74	0.258	0.120	2.19	None.	0.23	—	—	—	do.	2
3	0-30 cm.	7.03	9.52	0.197	0.125	2.45	0.87	1.113	0.38	1.43	0.00625	Bokod, Benguet, Mountain Province. ^b	3
4	do.	5.61	11.12	0.193	0.091	0.34	0.31	0.628	0.31	1.00	—	Daklan, Benguet, Mountain Province.	4
5	do.	8.33	12.77	0.183	0.078	0.09	0.18	0.642	0.34	2.12	—	do.	5
6	do.	9.53	13.99	0.286	0.231	0.19	0.13	0.473	0.24	2.36	—	Coffee grove adjacent to the <i>presidencia</i> .	6
7	do.	7.80	9.45	0.180	0.299	1.22	0.42	0.432	0.45	2.51	—	Rice paddies in the vicinity of the <i>presidencia</i> .	7
8	do.	7.99	10.57	0.217	0.285	1.76	0.93	1.369	0.43	2.34	0.00875	Updas, ^c Benguet, Mountain Province.	8
9	do.	7.97	11.55	0.237	0.083	1.51	0.43	0.082	0.60	2.85	0.00812	Bakung, ^e Benguet, Mountain Province.	9
10	do.	6.90	9.55	6.177	0.087	1.12	0.32	0.551	0.50	1.51	—	Lutab, ^e Benguet, Mountain Province.	10
11	do.	6.68	10.00	0.239	0.066	0.76	0.88	0.508	0.72	1.65	—	do. ^e	11
												Cabayan, ^f Benguet, Mountain Province.	
												First group of terraced rice paddies to the north.	
												Second group of terraced rice paddies north of Lutab.	

TABLE VIII. *Chemical analyses of Philippine soils*—Continued.

Number.	Specimen of soil.	Fine earth, water free basis.										Fine earth.	Source.	Remarks.	Number.
		Moisture (H ₂ O).	Loss of ignition.	Nitrogen (N).	Phosphoric anhydride (P ₂ O ₅).	Lime (CaO).	Magnesia (MgO).	Potash (K ₂ O).	Soda (Na ₂ O).	Humus.	Soil acidity (per cent Ca CO ₃).				
12	0-30 cm	6.86	11.30	0.236	0.112	1.69	0.73	0.291	0.31	1.57	94.43	Cusurung, a Benguet, Mountain Province.	From the terraced rice paddies	12	
13	do	6.50	11.21	0.255	0.101	1.86	0.79	0.299	0.45	1.82	88.90	do. b	First group of terraced rice paddies to the north.	13	
14	0-50 cm		10.50	0.028	0.05	0.09		0.05				Baguio, Benguet, Mountain Province.		14	
15	do		11.05	0.056	0.06	0.09		0.04				do	Pine grove about 1 kilometer east of town.	15	
16	do		12.29	0.069	0.09	0.18		0.10				do	Canote field.	16	
17	do		14.64	0.186	0.14	0.15		0.07				do	Grass growth	17	
18	do		11.52	0.075	0.12	0.15		0.04				do	Coffee land	18	
19	do		18.74	0.155	0.12	0.18		0.46				do	Irish potato land	19	
20	do		12.83	0.13	0.10	1.00		1.71				Trinidad Valley, Benguet.	Experiment station loam; good crops.	20	
21	do		13.49	0.136	0.16	0.18		0.11				do	Experiment station loam; good	21	
22	do		17.73	0.119	0.20	0.31		0.05				do	vegetables.	22	
23	do		18.45	0.16	0.12	1.08		1.50				do	A. Rubira's farm; fertilized with manure, vegetables.	23	
24	do		12.93	0.08	0.12	0.48		0.13				do	Uncultivated loam, grass growth	24	
25	do		12.20	0.06	0.13	0.59		0.13				do	Black loam, rice land	25	
26		15.32	15.17	0.154	0.118	1.18		2.02				La Trinidad		26	
27		14.55	15.71	0.187	0.140	1.26		1.75				do		27	

28	0-20 cm	3.26	6.86	0.139	0.054	2.15	1.46	0.38	0.72	10.047	10.31	Manoaz, Nueva Ecija	Central Luzon school farm	28
29	20-30 cm	4.65	7.65	0.115	0.102	2.01	1.90	0.34	0.26	10.055	10.28	do	Government rice farm ^k	29
30	Surface	1.89	6.18	0.072	0.082	1.41						Murcia, Tarlac	Government rice farm	30
31	Subsoil	2.00	6.54	0.042	0.052	1.07						do	Government Experiment Station, ^l	31
32	0-15 cm	1.76	8.33	0.061	0.021	2.04						Slagalang, Manila	Government Experiment Station	32
33	15-30 cm	3.40	4.25	0.061	Trace	2.17						do	Government Experiment Station, ^m	33
34	0-15 cm	1.58	3.96	0.103	0.031	1.32						do	Government Experiment Station	34
35	15-30 cm	2.06	2.15	0.061	0.051	1.49						do	Government Experiment Station, ⁿ	35
36	0-15 cm	2.53	3.25	0.103	0.093	2.13						do	Government Experiment Station	36
37	15-30 cm	4.33	4.35	0.063	0.157	1.40						do	Government Experiment Station	37
38	15 cm	16.38		0.103	0.018	3.75	0.84					Manila	Botanical Garden ^o	38
39	15-45 cm	24.26		0.087	0.448	6.78	0.71					do		39
40	0-6 cm	19.58		0.172	0.186	7.00	0.37					do		40
41	Surface	6.96		0.118	0.064	2.41	0.15					Balanga, Bataan		41
42	Subsurface	5.44		0.085	0.042	2.10	0.62					do	Worn-out rice paddy	42
43	Subsoil	4.82		0.074	0.021	2.35	0.15					do		43
44	0-15 cm	2.09	5.07	0.107	0.041			0.05	0.46		84.4	Lamiao, Bataan		44
45	15-30 cm	2.44	4.52	0.088	0.051			0.02	0.26		87.8	do	From the nursery in the vicinity	45
46	0-15 cm	5.04	9.95	0.132	0.074			0.02	0.23		77.2	do	of the lower forest reserve sta-	46
47	15-30 cm	4.99	11.52	0.138	0.053			0.02	0.22			do	tion.	47
48	0-15 cm	3.59	6.31	0.119	0.041			0.04	0.19		91.2	do		48
49	15-30 cm	3.65	6.75	0.118	0.031			0.05	0.32		92.8	do	Taken from three different local-	49
50	0-30 cm	3.40	8.27	0.403	0.083			0.08	0.73		76.7	do	ties in the vicinity of the lower	50
51	do	2.42	5.48	0.006	0.006			0.02	0.73		80.8	do	station.	51
52	do	4.22	9.60	0.106	0.198			0.04	0.61		62.7	do	The samples should be fairly rep-	52
53	Below 30 cm	2.23	3.52	0.061	0.041			0.01	0.74		90.4	do	resentative of the whole area	53
54	do	3.92	7.03	0.171	0.094			0.08	0.70		73.4	do	of clear land. ^p	54
55	do	4.32	8.01	0.006	0.095			0.06	0.46			do		55
56		9.39	19.77	0.336	0.149	0.23		0.09	0.37		74.4	do	Taken on the mountain in the	56
57		9.06	13.98	0.205	0.111	0.13		0.05	0.29		77.7	do	vicinity of the upper (third)	57
58		9.04	14.67	0.150	0.091	0.07		0.04	0.28		69.0	do	forest reserve station.	58
59		9.44	17.24	0.190	0.125	0.23		0.10	0.23		70.8	do		59
60	0-15 cm	6.98	12.76	0.032	0.065	0.13		0.12	0.25	3.99		do		60

TABLE VIII.—*Chemical analyses of Philippine soils*—Continued.

Number.	Specimen of soil.	Fine earth, water free basis.										Fine earth.	Source.	Remarks.	Number.
		Moisture (H ₂ O).	Loss on ignition.	Nitrogen (N).	Phosphoric anhydride (P ₂ O ₅)	Lime (CaO).	Magnesia (MgO).	Potash (K ₂ O).	Soda (Na ₂ O).	Humus.	Soil acidity (per cent Ca CO ₃).				
61	15-30 cm.	7.59	14.44	0.130	0.087	0.28		0.10	0.22	2.77			Linao, Bataan	Bataan forest ridge soil	61
62	Surface	6.99	9.08	0.161	0.075	1.13		0.13	1.05	2.28			do		62
63	do	6.84	12.03	0.153	0.121	0.22		0.11	0.23	3.29			do		63
64	do	9.03	10.75	0.11	0.050	0.85	0.20	0.151	0.50	3.51	0.0125	99.5	Near Alibung, Rizal	Bataan forest terrace soil	64
65	Subsoil	11.13	12.06	0.07	0.094	1.05	0.37	0.178	0.44	3.62	0.0112	99.3	do		65
66	Surface	9.56	10.76	0.12	0.096	0.83	0.38	0.217	0.52	4.56	0.0075	98.5	do		66
67	Subsoil	11.15	11.34	0.07	0.042	1.02	0.51	0.172	0.72	4.27	0.0112	97.7	do		67
68	Surface	7.83	10.69	0.14	0.095	0.78	0.40	0.285	0.33	2.16	0.0087	99.1	do		68
69	Subsoil	11.06	12.24	0.02	0.057	0.95	0.39	0.206	0.58	2.30	0.0127	99.4	do	Planted to sugar cane	69
70	Surface	7.85	11.13	0.14	0.085	1.11	0.32	0.240	0.48	3.33	0.0075	98.8	do		70
71	Subsoil	10.16	13.18	0.08	0.078	0.73	0.28	0.184	0.62	1.35	0.0100	99.0	do		71
72	Surface	9.95	11.49	0.12	0.128	1.06	0.37	0.129	0.30	2.22	0.0062	99.2	do		72
73	Subsoil	11.14	12.07	0.08	0.105	1.08	0.28	0.138	0.22	1.45	0.0050	99.5	do		73
74		8.97	12.59	0.121	0.077	0.78		0.17	0.57			98.2	San Francisco de Malabon, Cavite	First-class rice soil ^a	74
75		4.98	8.48	0.147	0.081	0.88		0.20	0.26			67.9	do	Rock 12.5 cm. below surface ^c	75
76		8.73	12.90	0.153	0.110	0.53		0.20	0.32			95.4	Imus, Cavite	First-class rice soil ^b	76
77		8.73	11.98	0.109	0.121	0.95		0.13	0.18			99.1	do	Dark clay ^e	77
78		8.46	12.13	0.076	0.098	0.58		0.21	0.37			96.6	Buena Vista, Cavite	Loam ^f	78
79		9.68	12.16	0.110	0.122	0.56		0.20	0.90			98.8	Dasmariñas, Cavite	Loam ^g	79
80	Surface		7.34	0.15	0.05	0.46		0.22					Batang, Laguna		80

[illegible]

TABLE VIII.—*Chemical analyses of Philippine soils—Continued.*

Number.	Specimen of soil.	Fine earth, water free basis.								Fine earth.	Source.	Remarks.	Number.
		Moisture (H ₂ O).	Loss on ignition.	Nitrogen (N).	Phosphoric anhy- dride (P ₂ O ₅).	Lime (CaO).	Magnesia (MgO).	Potash (K ₂ O).	Soda (Na ₂ O).	Humus.	Soil acidity (per cent Ca CO ₃).		
114	0-30 cm.	6.87	8.75	0.301	0.127	1.05	1.15	0.96	0.30	3.35	0.0005	Mangarin Mindoro.	114
115	do	10.20	9.07	0.286	0.147	1.09	0.93	1.08	0.37	3.98	0.0038	do	115
116	do	1.55	3.70	0.194	0.059	2.42	0.93	0.28	0.37	1.35	0.0019	Bug Bug River cane field.	116
117	do	4.11	8.12	0.272	0.163	0.55	0.54	0.91	0.34	2.89	0.0032	do	117
118	do	9.93	10.60	0.253	0.353	1.08	Trace	0.49	0.70	4.00		Bulalacao, Mindoro	118
119	do				0.08	0.13	Trace			4.00		Culion	119
120	do				0.21	0.07	Trace			4.00		do	120
121	do				0.07	0.15	Trace			4.00		do	121
122	do	4.10	9.15	0.167	0.003	3.22		0.006	0.65			Paragua	122
123	do	5.28	12.30	0.137	trace	0.70		0.004	0.20			do	123
124	do	4.72	10.20	0.115	0.010	2.68		0.007	0.48			Iwahig penal settlement	124
125	do	3.62	7.35	0.124	0.010	3.04		0.006	0.20			do	125
126	Surface	2.23	6.02	0.092	0.123	2.55	0.62	0.16	0.50			Iwahig penal settlement field	126
127	Subsoil	3.20	7.46	0.124	0.093	3.88	0.16	0.15	0.53			No. 8.	127
128	Surface	2.43	5.26	0.062	0.103	2.52	0.29	0.18	0.23			Iwahig penal settlement field	128
129	Subsoil	3.74	7.70	0.114	0.114	1.12	0.34	0.04	0.72			No. 1.	129
130	Surface	4.85	9.65	0.168	0.200	2.36	0.13	0.21	0.95		10.18	Bolikaw	130
131	Subsoil	5.15	9.15	0.116	0.148	1.56	0.12	0.17	0.92		10.15	do	131
132	Surface	2.64	4.97	0.093	0.133	2.00	0.18	0.14	0.61		10.26	Mangahan	132
133	Subsoil	2.79	6.85	0.165	0.113	2.04	0.19	0.15	0.61		10.23	do	133
134	do	3.66	3.11	0.101	0.033	1.59		0.05	0.23			Capiz	134
135	do	8.85	8.50	0.176	0.249	1.55		0.44	0.52			Capiz	135
136	do	8.96	12.43	0.189	0.106	0.90		0.32	1.81			do	136

137	7.08	9.96	0.117	0.237	1.48	0.34	2.78	98.0	do	137
138	6.99	6.54	0.110	0.229	1.15	0.53	2.58	83.0	do	138
139	6.02	8.29	0.187	0.896	2.63	0.21	0.48	88.0	do	139
140	0-30 cm	4.34	6.76	0.199	0.051	0.82	0.14		Balasan, Panay	140
141	Subsoil	4.22	5.84	0.203	0.050	0.39	0.11		do	141
142	10.00	9.40	0.088	0.172	1.61	0.67	0.27	81.7	Holilo, Panay	142
143	Surface	7.94	12.60	0.152	0.152	0.13	0.065	85.2	La Carlota, Occidental Negros.	143
144	do	11.90	11.87	0.216	0.420	0.73	0.35	83.5	do	144
145	0-80 cm	10.91	15.38	0.408	0.160	0.79	0.22		La Castellana, Occidental Negros.	145
146	Subsoil	15.43	12.81	0.261	0.138	0.89	0.26		do	146
147	do	5.98	20.70	0.35	0.77	1.31	0.106		Siquijor	147
148		1.08	5.85	0.20	0.05	0.20	0.15	0.80	Port Banga, Zamboanga.	148
149	0-10 cm	14.42	18.92	0.164	0.187	0.41	0.23	2.17	Mindanao	149
150	10-40 cm	16.61	19.47	0.216	0.180	0.37	0.26	2.12	do	150
151	40-50 cm	13.49	19.75	0.208	0.173	0.58	0.36	3.33	do	151
152	0-10 cm	6.31	12.07	0.195	0.126	1.66	0.161	4.15	do	152
153	10-40 cm	3.56	7.30	0.173	0.097	2.24	0.173	2.55	do	153
154	40-50 cm	15.15	18.48	0.318	0.141	0.42	0.217	5.90	do	154
155	0-10 cm	13.78	12.58	0.220	0.162	2.06	1.45	3.68	Reina Regente, Mindanao.	155
156	10-40 cm	14.80	11.90	0.141	0.129	1.77	1.64	2.31	do	156
157	40-50 cm	14.90	10.38	0.094	0.153	1.74	1.67	2.44	do	157
158	0-10 cm	19.13	12.67	0.235	0.223	1.80	2.10	4.35	Fort Pitkit, Mindanao.	158
159	10-40 cm	18.47	11.39	0.184	0.196	1.92	2.31	3.25	do	159
160	40-50 cm	14.64	10.92	0.222	0.175	1.81	2.30	2.09	do	160
161		8.85	10.16	0.207	0.142	0.87	0.29	0.76	Cotabato, Mindanao	161
162		5.74	9.10	0.170	0.117	0.63	0.17	0.67	do	162
163		7.39	13.20	0.276	0.201	0.31	0.27	0.47	do	163
164	0-10 cm	3.23	5.49	0.114	0.186	1.80	0.63	2.15	Surangani, Mindanao.	164
165	10-40 cm	4.48	5.58	0.115	0.188	3.18	0.71	2.17	do	165
166	40-50 cm	3.95	4.78	0.062	0.218	3.28	0.72	1.61	do	166

Sample represents 1,000 hectares.

North side of Lake Lanao.

South side of Lake Lanao.

TABLE VIII.—*Chemical analyses of Philippine soils*—Continued.

Number.	Specimen of soil.	Fine earth, water free basis.								Fine earth.	Source.	Remarks.	Number.
		Moisture (H ₂ O).	Loss on ignition.	Nitrogen (N).	Phosphate anhydride (P ₂ O ₅).	Lime (CaO).	Magnesia (MgO).	Potash (K ₂ O).	Soda (Na ₂ O).	Humus.	Soil acidity (per cent Ca CO ₃).		
167	-----	8.21	14.07	0.009	0.130	0.52	-----	0.14	0.74	-----	-----	-----	167
168	-----	2.50	12.50	0.006	0.133	0.60	-----	0.13	0.72	-----	-----	-----	168
169	-----	7.72	14.61	0.146	0.173	0.20	-----	0.12	0.39	-----	-----	-----	169
170	-----	8.51	19.37	0.163	0.218	0.34	-----	0.06	0.20	-----	-----	-----	170
171	-----	4.02	10.93	0.029	0.052	0.09	-----	0.05	0.66	-----	-----	-----	171
172	-----	8.91	12.12	0.061	0.006	0.10	-----	0.04	0.42	-----	-----	-----	172
173	-----	12.81	14.70	0.079	0.103	0.03	-----	0.11	0.38	-----	-----	-----	173
174	-----	8.28	11.81	0.036	0.033	0.05	-----	0.09	0.24	-----	-----	-----	174
175	-----	8.36	15.96	0.203	0.153	1.16	-----	0.08	0.12	-----	-----	-----	175
176	-----	4.85	12.11	0.079	0.126	0.06	-----	0.04	0.20	-----	-----	-----	176
177	-----	4.25	19.55	0.162	0.125	0.06	-----	0.06	0.11	-----	-----	-----	177
178	-----	-----	-----	-----	0.153	5.41	-----	1.87	-----	-----	-----	-----	178
179	-----	-----	-----	-----	0.344	5.12	-----	1.79	-----	-----	-----	-----	179
180	-----	-----	9.40	0.250	0.180	-----	-----	0.32	-----	-----	-----	-----	180

^a The per cent of calcium carbonate required by the soil.

^b In the Mountain Province practically the only method of fertilization extensively employed for rice is that of soil-transfer. This consists in periodically flooding each terrace with water heavily charged with soil from the mountain sides above. In this way a film of new soil is deposited over the fields and is afterwards mixed in. The process is repeated about every two years. In constructing a rice terrace, the surface soil is first excavated, a retaining wall built, the bottom of the enclosure covered with a layer of impervious clay above which is placed a layer of sand and gravel and finally the top layer, which the analyses show is in most cases very fertile, is formed of the original surface soil supplemented by soil carried in from a convenient point. The supplementary soil is often from the same source as the soil later used for fertilization. The percentage composition of the mineral plant food materials in the soil transferred cannot be greatly different from the previous top soil of the terrace; even if it were higher the amount imported is too small materially

to change the composition of the whole. Therefore the beneficial effects noted by the use of the soil transfer method can scarcely be attributed to the addition of inorganic constituents. It is possible that in the two years in which the paddy has been kept flooded and planted to rice that the beneficial bacteria in the soil have been depleted and that by the soil transfer method the field has become again inoculated and the fertility thus increased.

^c See Plate I, figs. 1 and 2.
^d Five representative places and five variations.

^e See Plate I, fig. 3.

^f See Plate II, fig. 1.

^g See Plate II, fig. 2.

^h See Plate III, fig. 1.

ⁱ Sulphuric anhydride.

^j Manganese as Mn_2O_3 .

^k W. C. Welborn, former Director of Agriculture, says: "These samples seem to be fairly representative of the great body of land lying along the Manila and Dagupan Railway between Manila and Murcia."

^l "Manured in this year," dated July 17, 1903.

^m "Dressed heavily with city stable manure."

ⁿ See Plate V, fig. 2; Plate VI, figs. 1 and 2; Plate VII, fig. 1.

^o See Plate IV, fig. 1.

^p See Plate VII, fig. 2; Plate VIII, figs. 1 and 2.

^q A sticky and tenacious black clay. The field has plenty of water for irrigation and produces good crops.

^r A lighter clay than the above. Does not produce well notwithstanding an abundance of water.

^s Does not produce well, principally because of an insufficient supply of water.

^t High and unirrigated, but grows a fair crop of sugar cane.

^u High and unirrigated, but grows a good crop of sugar cane.

^v This represents the field on the right side of the road entering the college grounds.

^w This represents the field on the left side of the road entering the college grounds.

^x There were 31.3 per cent of coarse stones which were removed before the percentage of fine earth was determined.

^y W. C. Welborn says: "This soil is so deep and appears so uniform in composition that top soil samples are deemed sufficient."

Some of the above samples represent small areas, others exceptionally large ones and still others unusual or peculiar conditions. Certain ones represent soils of known low fertility and the analyses were undertaken in order to determine the cause: barring these, the data show that Philippine soils are highly fertile.

From the chemical standpoint alone I believe that in the Philippines it is the abnormal virgin soil that is not inherently suited to the majority of crops.

Many attempts have been made to classify and to explain the relative productivity of soils according to the results of chemical analyses, but the problem is too intricate; often the percentage of the various constituents bears no necessary relation to the crop producing power, for the chemical composition is only one of many factors involved in the soil problem.

PHYSICAL ANALYSES.

A consideration of the physical composition of a soil is very important. There are instances where two soils having the same chemical composition and physical texture showed themselves to be very different, owing to local peculiarities, but other things being equal the physical nature (the amount of organic matter and the size of the inorganic grains) bears a close relation to crops and will often explain conditions encountered.

The organic and mineral constituents of a soil may indicate high fertility but the physical condition may be such as to render it the opposite. A soil which contains a large amount of sand or humus is usually porous, on the other hand one in which the content of these constituents is small is usually stiff and impervious to water. To be productive a soil must have gravel, sand, clay and silt in the proper proportions not to be impervious to water and air. Variation in the amount of humus is frequently the essential difference between a soil and its subsoil, the latter having the less organic matter, although there also may be a marked difference in the porosities of the two.

The porosity, the aëration and toxicity, the water holding and absorbing power, the movement and distribution of the moisture and soluble constituents of the soil, and the depth of the water table depend largely on the texture and, therefore, the drainage of a soil and its resistance to drought are intimately connected with its physical nature. These same factors in turn control the character and quantity of beneficial bacteria in the soil.

Some crops require an abundance of water during a certain period while others require a uniformly moist soil. Lowland rice, an example of the former, in most regions is usually grown on a heavy soil with an impervious subsoil in order that it may have sufficient water during the growing period. Such a soil, unless it is very rolling, would probably

need both drainage and irrigation for crops of the latter type, such as sugar cane, coconuts or hemp. In general, it would not be economical to grow sugar cane on a soil that has too little retentive power for moisture, nor on a soil which is so impervious as to require drainage, any more than it would be economical to grow rice on a very sandy soil with a porous subsoil, because of the excessive amount of water necessary. I believe that in the Philippines most soils consisting of a sandy loam to a loamy clay will produce almost any crop abundantly if the water supply is carefully controlled, while the light, sandy soils should be restricted for the present to crops which do well with little water, such as peanuts or mulberries and the heavy or clayey soils utilized for the cultivation of rice.

For the determination of physical composition of soils the centrifugal method, practically as outlined in the United States Department of Agriculture, Bureau of Soils, Bulletin Number 24, has been used in this laboratory and gives fairly concordant results.¹²

Unpublished analyses by this method are given in Table IX. Those by the Schöne method in Table XVII.

METHOD OF PHYSICAL ANALYSIS.

While fairly satisfactory in the hands of trained men, the centrifugal method allows of a large personal equation. In this country where we have oriental assistants without technical training, any method which may be reduced to an empirical one is most advantageous and permits the saving of much time. Schöne's method is superior in this respect.

Schöne's method¹³ depends on the separation of soil into particles of various sizes by the use of a stream of water moving vertically and regulated by a piezometer so as just to equal the resistance of the largest particles intended to be removed. This resistance depends on the form and also on the specific gravity of the grains and in order to calculate its value normals for these factors must be assumed, namely, the form of a sphere and the specific gravity of quartz (2.65). According to Newton's law of gravity Schöne worked out a formula which might serve to solve the problem whether by this or that velocity of the current (v) silt particles of this or that diameter will be removed, that is, that in a given case, the velocity of the current in the apparatus is just sufficient to counteract the tendency of a given particle to sink; all particles of a smaller diameter will be carried on by the current, while all of a greater diameter will settle out. Objection has been raised to this method on the ground that the silt particles vary too much in specific gravity to permit of any one value being taken as the specific gravity of the whole. The results of analysis show that the application is not rigid and in order to have the theoretical formula agree with the analysis it has to be modified empirically to read $d = v \sqrt{r} \times 0.0314$ mm, where d is the diameter of the silt particle. I have checked this empirical formula with the aid of a microscope and a stage micrometer and have concluded that it is as accurate as any method yet proposed.

¹² Pratt, *This Journal*, Sec. A (1911), 6, 35.

¹³ Ueber Schlammanalyse, *Bull. de la Soc. impériale des naturalistes de Moscou* (1867), 40, Pt. I, 324; *Ztschr. f. analyt. Chem.* (1868), 7, 29; Wiley, H. W., *Principles and Practice of Agricultural Analysis*, Easton, Pa., 2nd ed. (1906), 1, 231. In compiling the description of the apparatus all of these have been used.

TABLE IX.—*Mechanical analyses of some of the above Philippine soils.*^a

[Numbers give percentages.]

Num- ber.	Specimen of soil.	Detritus not passing 1 mm. sieve.	Fine earth water free basis.					Source.	Remarks.
			Coarse sand, 1 to 0.5 mm.	Medi- um sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.10 mm.	Very fine sand, 0.10 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, less than 0.005 mm.	
81	0-30 cm.---	Very small.	0.68	0.97	5.47	6.16	43.08	43.36	99.72
82	Subsoil.---	Very small.	0.69	2.52	2.72	6.14	42.78	45.59	100.44
83	0-30 cm.---	Very small.	1.42	4.03	5.69	5.08	44.88	38.71	99.81
84	Subsoil.---	Very small.	1.59	4.07	5.16	4.91	46.06	38.82	100.11
85	Surface.---	5.46	3.35	6.44	6.52	9.46	35.80	39.21	100.78
86	Subsoil.---	7.25	2.81	6.41	6.62	9.58	32.68	42.13	100.23
87	Surface.---	8.63	4.63	9.39	10.33	10.99	31.61	33.38	100.33
88	Subsoil.---	8.88	3.58	6.62	6.80	8.62	32.12	40.20	99.90
114	---	0.00	3.72	9.08	6.98	2.31	28.37	50.25	100.71
115	---	0.00	0.03	0.22	1.50	1.49	38.47	58.80	100.56
116	---	9.76	8.98	46.50	26.58	3.55	7.42	7.39	100.42
117	---	0.00	0.00	0.26	1.29	11.19	56.93	31.00	100.67
140	0-30 cm.---	Small.	2.63	12.06	17.71	20.11	23.33	24.33	100.17
141	Subsoil.---	Small.	1.59	9.56	17.20	20.25	30.72	21.11	100.43
145	0-30 cm.---	Small.	2.82	9.92	10.40	10.41	39.34	27.06	99.95
146	Subsoil.---	Small.	3.23	9.48	10.91	9.85	28.83	38.34	100.64
149	0-10 cm.---	Small.	4.95	15.36	21.20	13.83	27.21	18.12	100.67
150	10-40 cm.---	Small.	2.61	13.20	18.80	13.82	28.48	23.61	100.52
151	40-50 cm.---	Small.	2.99	13.40	18.78	11.28	30.46	23.69	100.60
152	0-10 cm.---	2.46	5.62	24.07	24.10	18.42	22.15	5.79	100.16
153	10-40 cm.---	2.29	3.81	27.68	24.81	18.09	20.45	5.35	100.19
154	40-50 cm.---	1.96	7.46	19.18	22.05	17.80	26.81	7.02	100.32
155	0-10 cm.---	Small.	0.12	1.31	6.46	7.73	61.66	22.17	99.45
156	10-40 cm.---	Small.	0.32	0.59	3.98	8.42	67.48	18.41	99.20

These samples represent an area
of about 3,800 hectares of the
Calamba Sugar Estate Co.

Cf. footnote "v," Table I.

Cf. footnote "w," Table I.

Wells camp cane field.

Cane field near Japanese camp.

Bug Bug River cane field.

San Jose field.

157	40-50 cm	Small.	0.18	0.54	4.96	7.23	65.34	21.23	99.48	do
158	0-10 cm	Small.	0.31	3.48	7.54	11.35	65.71	12.71	100.56	Fort Pikit, Mindanao
159	10-40 cm	Small.	0.99	4.38	7.11	13.81	59.30	14.11	99.65	do
160	40-50 cm	Small.	1.49	6.86	11.28	12.96	53.12	13.87	99.59	do
164	0-10 cm	Small.	10.25	21.89	25.40	14.51	20.86	7.27	100.18	Sarangani, Mindanao
165	10-40 cm	Small.	5.76	19.37	25.84	18.08	23.20	7.89	100.14	do
166	40-50 cm	Small.	7.51	20.17	30.80	18.55	18.59	4.14	99.76	do

^a Most samples indicate alluvial soil.

No apparatus seems to offer advantages over Schöne's elutriation apparatus with the modification that it should be supplemented by a second elutriating tube as described by Osborne¹⁴ in which all of the soil except a portion of the

clay and fine silt is at first placed. The apparatus used by me was obtained from Germany and is similar to that described by Schöne except that each unit has the second elutriating tube of narrow bore and with straight sides to precede the Schöne's tube proper. A complete apparatus in use by me is shown in figure 8 and figure 9 is a detail picture of the outflow tube.

The diameters of the two tubes were accurately measured and that of their straight-sided parts was found by careful calibration to be comparable, as they should be, in all parts. The diameters of the small tube *A* and the large tube *B* calculated according to the formula

$D = \sqrt{\frac{4z}{\pi h}}$ centimeters were found to be 2.456 and 4.990 centimeters respectively. In the formula *D* is the diameter, *z* the cubic centimeters of water to a given, exactly measured height (*h*) of tube.

By means of the stopcock *x* controlling the pressure, the feed water can be regulated and the outflow at *y* measured under given heights in the piezometer. The law of hydraulic outflow enables one to compute the outflow for any given height from a known value according to the equation $Q = \frac{a}{t}$ cubic centimeters where

Q is the outflow per unit of time and (*a*) the number of cubic centimeters flowing in (*t*) units of time. A correction, which for the purpose of this apparatus may be taken as constant, must be subtracted for the retardation due to capillary attraction. This factor (*C*) may be calculated by measuring the quantity which flows out at two different heights of the column of the piezometer according to the equation

$$\sqrt{h_1 - C} : \sqrt{h_2 - C} = Q_1 : Q_2$$

$$\text{or } C = \frac{Q_1^2 h_2 - Q_2^2 h_1}{Q_1^2 - Q_2^2} \text{ cubic centimeters,}$$

where (*h*) is the observed height of the water in the piezometer. For the most exact determination one chooses the lowest and highest from which an exact reading can be made. I obtained the following results.

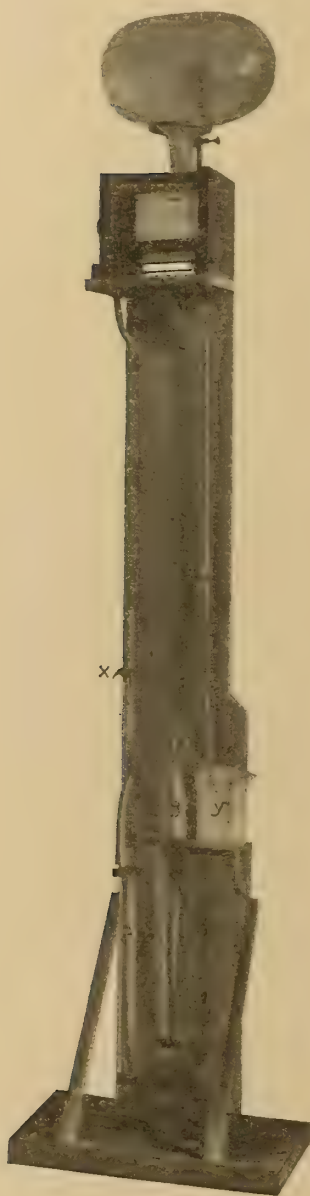


FIG. 8.—Modified Schöne apparatus for the mechanical analysis of solis.

¹⁴ *Conn. Agri. Exp. Sta., Ann. Rep.* (1887), 144 et seq.

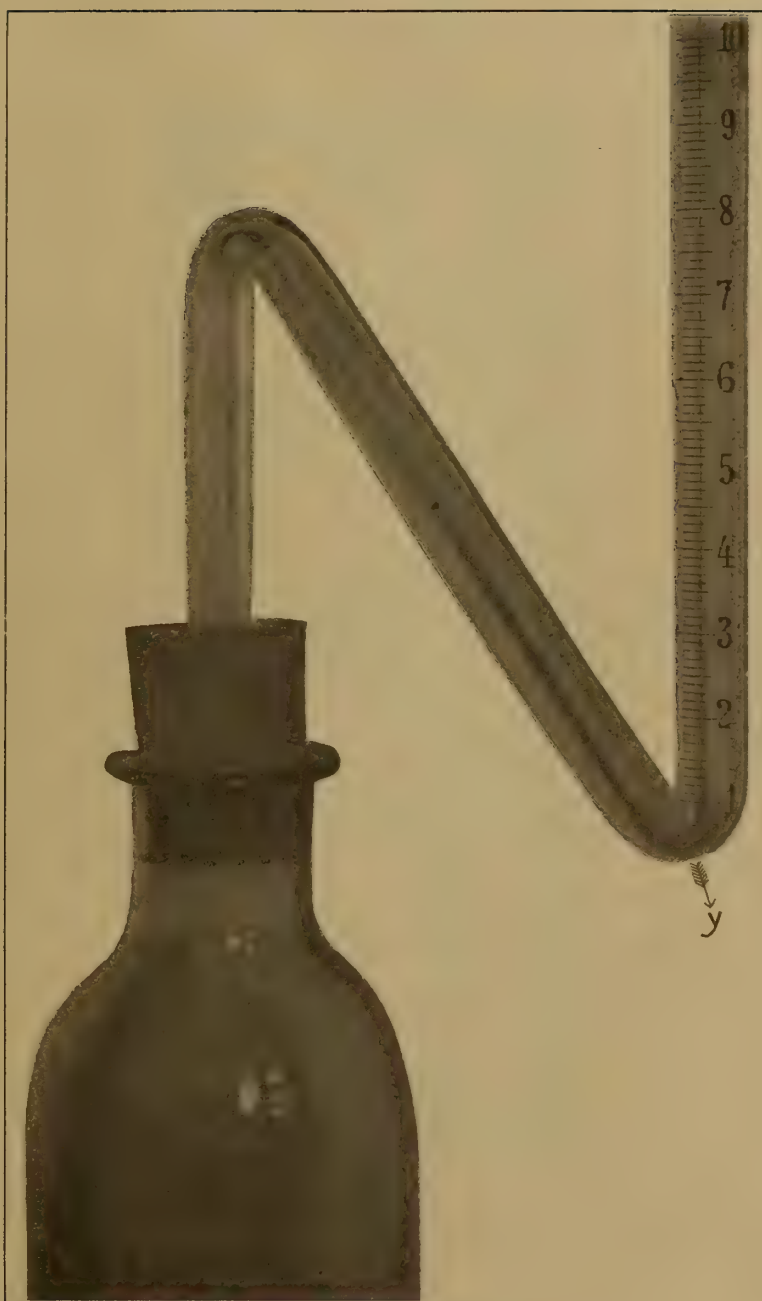


FIG. 9.—Detail picture of the outflow tube and piezometer.

TABLE X.—*The effect of capillary attraction on the height of the column of water in the piezometer.*

Observed height in centimeters.		Observed quantity of outflow per minute in cubic centimeters (grams).		Height of column in centimeters to be subtracted due to capillary attraction.
h_1	h_2	Q_1	Q_2	C
80	1.8	349.90	17.96	1.593
90	1.8	370.75	17.96	1.593
80	1.9	349.90	21.94	1.592
90	1.9	370.75	21.94	1.590
80	2.0	349.90	25.36	1.589
90	2.0	370.75	25.36	1.590
80	2.1	349.90	28.51	1.58
90	2.1	370.75	28.51	1.58
				^a 1.59

^a Mean.

When the quantity of water which leaves the outflow orifice y in a unit of time has been measured, we know that the same quantity has simultaneously passed over a cross section of each elutriating tube and we have therefore, $v = Q \frac{4}{\pi D^2}$ centimeters. The velocity in each elutriating tube is directly proportional to the quantity of water passing, hence

$$v : v_n = \sqrt{h-C} : \sqrt{h_n-C} \quad (1)$$

$$\text{therefore } v_n = \sqrt{h_n-C} \left(\frac{v}{\sqrt{h-C}} \right) \quad (2)$$

$$\text{and } h_n = v_n^2 \frac{h-C}{v^2} + C. \quad (3)$$

I obtained the constant $\frac{h-C}{v^2}$ from the following data:

TABLE XI.—*Derivation of the constant $\frac{h-C}{v^2}$.*

Observed height in centimeters.	Observed quantity of outflow in cubic centimeters.	Corresponding velocity in tube B in centimeters per minute.	Constant $\frac{h-C}{v^2}$.
1.8	17.96	0.9184	^a 0.249
1.9	21.94	1.122	0.246
2.0	25.36	1.297	0.244
2.1	28.51	1.458	0.240
80.0	349.90	17.892	0.245
90.0	370.75	18.957	0.246
			^b 0.245

^a When the unit of time is a second the constant will be multiplied by (60)².

^b Mean.

Substituting for the constant $\frac{h-C}{v^2}$ its value in (3) and (2) we obtain

$$h_n = 0.245 v_n^2 + 1.59 \text{ (centimeters).}$$

$$v_n = \sqrt{h_n - 1.59} \times 2.02 \text{ (centimeters per minute).}$$

In order to be able to determine the velocity of the water at any given instant in the elutriating tubes and therefore the corresponding diameter of the soil particles in suspension a large number of values are computed in accordance with the above formula and tabulated as follows:

TABLE XII.—*The height of the water in the piezometer required to remove soil particles of given diameters.*

Height in piezometer in centimeters. h.	Velocity in millimeters per sec. in the elutriating tubes. v.		Corresponding diameter of soil particles in millimeters. d.	
	Tube B. ^a	Tube A.	Tube B.	Tube A.
1.8	^b 0.154	0.636	0.0095	0.0235
1.83	0.166	0.685	0.0100	0.0247
2.0	^c 0.216	0.892	0.0118	0.0296
2.5	0.321	1.326	0.0152	0.0376
3.0	0.400	1.651	0.0175	0.0432
3.5	0.465	1.921	0.0193	0.0476
4.0	0.523	2.159	0.0208	0.0512
4.5	0.574	2.370	0.0221	0.0544
5.0	0.622	2.568	0.0232	0.0572
6	0.707	2.919	0.0252	0.0620
7	0.783	3.232	0.0269	0.0662
8	0.853	3.519	0.0284	0.0699
9	0.917	3.784	0.0297	0.0732
10	0.977	4.031	0.0309	0.0762
15	1.233	5.090	0.0359	0.0884
20	1.445	5.965	0.0397	0.0978
21.24	1.496	6.175	0.0406	0.1000
25	1.629	6.709	0.0428	0.1054
30	1.782	7.356	0.0454	0.1118
35	1.947	8.037	0.0480	0.1183
39.6	2.077	8.574	0.0500	0.1232
40	2.087	8.615	0.0502	0.1236
45	2.218	9.156	0.0521	0.1285
50	2.343	9.672	0.0540	0.1331
60	2.573	10.623	0.0573	0.1413
70	2.785	11.497	0.0603	0.1485
80	^d 2.982	12.310	0.0644	0.1551
90	^e 3.165	13.065	0.0654	0.1611
100	3.340	13.788	0.0677	0.1668

^a The velocity in this straight-sided tube is 4.128 times that in the large tube for this number expresses the relation of the square of the respective radii.

^b Observed 0.153.

^c Observed 0.216.

^d Observed 2.982.

^e Observed 3.160.

A 20-gram sample of air-dried soil is taken for each analysis. That portion which remains in suspension after disintegration (cf. p. 320 et seq.) is carefully decanted into the Schöne tube of the apparatus and the coarser portion rinsed into the straight-sided tube. The apparatus is closed, the stopcock opened so that the water is allowed slowly to enter, care being taken to avoid attaining more than the lowest required velocity until the air is expelled and the outflow begins.

From Table XII it will be seen that if the pressure in the apparatus is adjusted by means of the stopcock so that the height of the water in the piezometer is 1.83 centimeters and the flow is maintained sufficiently long all silt and clay particles of less diameter than 0.01 millimeter will be floated out of the apparatus at the orifice *y*. About 4 liters of water are required to complete this operation. This water is allowed to stand 24 hours in 20-centimeter columns and that portion which does not settle is siphoned off and called clay, whereas the residue is termed fine silt. The largest particles of the former are about 0.002 millimeter in diameter. The clay may be directly determined by evaporating to dryness and weighing, or by evaporating only an aliquot part, but in most cases it is sufficiently accurately determined by difference.

If the pressure is now changed so that the height of the water in the piezometer is 21.24 centimeters all silt and sand particles of less diameter than 0.1 millimeter will be removed from the tube *A*. When this is complete the stopcock is closed, the piezometer replaced by a solid rubber stopper and tube *A* removed from the system and the stopcock *x* directly connected with tube *B*. When the piezometer is again in place the stopcock is next opened so that the pressure in the piezometer is 39.6 centimeters and the flow continued until all particles less than 0.05 millimeter in diameter pass out at the orifice *y* when they are combined with those which passed out at 21.24 centimeters pressure. We have then separated our soil into the following sizes:

Clay (diameter less than 0.002 millimeter) which was carried over at a pressure of 1.83 centimeters but remained in suspension.

Fine silt (diameter 0.01 to 0.002 millimeter) which was carried over at a pressure of 1.83 centimeters but settled out in 24 hours.

Silt (diameter 0.05 to 0.01 millimeter) which was carried over at a pressure of 1.83 to 39.6 centimeters.

Fine sand (diameter 0.1 to 0.05 millimeter) which was carried out of tube *A* and remained in tube *B* at a pressure of 39.6 millimeters.

Sand (diameter greater than 0.1 millimeter) which remained in tube *A* at a pressure of 21.24 millimeters.¹⁵

Each of these fractions is united in or transferred to a single beaker and after the clear water from each has been siphoned off they are transferred to porcelain crucibles, evaporated, dried in an air bath at 110°, ¹⁶ cooled in a desiccator, and weighed promptly. The sand is usually further divided by passing through sieves which retain the grains of 0.5 and 0.25 millimeter in diameter respectively. These fractions are weighed and the sand of 0.25 to 0.1 millimeter diameter determined by difference. This is sufficiently accurate because grains of these sizes flocculate only slightly if any on drying.

The soil must be thoroughly disintegrated.—Complete disintegration of the aggregates can be the only basis of comparison, for the aggregates in soil are not constant. In general there are many substances, foremost among which are acids, which promote flocculation, while alcohol, ether, alkalies, etc., inhibit it.¹⁷

¹⁵ This may be further divided by passing it under water through sieves of desired sizes.

¹⁶ Three to four hours is enough to insure complete drying.

¹⁷ There are several theories to account for the formation and breaking down of these flocules. Ostwald, *Wo. Grundriss der Kolloidchemie*, Dresden. (1910), 380 et seq. Hardy, W. B. *Proc. Roy. Soc.* (1899), 66, 95, 112. Puchner, Heinrich. *Landw. Vers. Sta.* 70, 249. Fickendey, E. *Königsberg i. Pr. J. Landw.* 54, 343. *U. S. Geol. Surv. Bull.* (1909), 388, 15.

An attempt was made to prepare the sample by passing under water through a sieve of 0.25-millimeter mesh as indicated by Schöne, but no concordant results were obtained owing to imperfect disintegration of the floccules. Although disintegration can not be accomplished by passing through a sieve it can be done satisfactorily by shaking the samples for six hours in 250-cubic-centimeter bottles together with about 75 cubic centimeters of distilled water to which 10 drops of ammonia has been added.¹⁸

Some of my results in substantiation of these statements are given in Table XIII.

TABLE XIII.^a—Comparison of the disintegration of soils by shaking and by passing under water through a sieve.

[Numbers give percentages.]

Soil.			Air-dried sample disintegrated by shaking 6 hours in water.					
Num-ber.	Color.	Depth in cm.	Sand, 1.0 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, <0.002 mm.	Total.
1	Light brown -----	0-15	15.55	14.23	22.11	33.08	15.47	100.89
		0-15	15.80	13.00	23.53	32.25	15.54	100.12
2	Black -----	0-15	27.26	17.66	12.38	28.64	13.64	99.58
		0-15				29.16	14.46	
3	Brown -----	0-15	20.74	17.80	16.64	34.84	9.67	99.69
		0-15	20.40	16.85	15.80	37.00		
4	(c)	15-30	18.97	16.51	6.81	34.30	33.46	100.05
		15-30	17.60	14.38	9.19	36.42	23.70	101.29

Soil.			Air-dried sample disintegrated by passing under water through a sieve. ^b					
Num-ber.	Color.	Depth in cm.	Sand, 1.0 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, <0.002 mm.	Total.
1	Light brown -----	0-15	34.46	16.71	36.53	10.48	1.79	99.95
		0-15	22.44	14.90	31.65	25.96	5.01	100.04
2	Black -----	0-15	21.00	27.34	24.71	22.56	3.51	99.12
		0-15	21.24	27.86	20.51	24.55	5.05	98.71
3	Brown -----	0-15	27.56	18.54	42.58		12.85	101.53
		0-15						
4	(c)	15-30	36.19	23.09	29.43	8.42	2.39	99.52
		15-30						

^a Moisture separately determined and the results calculated to the dry basis. All clay percentages were obtained by direct determination.

^b That portion which would not pass the 0.25-millimeter sieve was weighed separately and added to the largest fraction.

^c Subsoil of No. 3.

A comparison of the relative sizes of the grains given above, shows the magnitude of the error when the soil is only passed through a sieve.

The soil should not be oven dried before it is disintegrated and separated into the individual fractions. The conclusion has been indicated, though not rigidly drawn, that "drying a soil at 110°C does not seriously modify its mechanical com-

¹⁸ Bull. U. S. Dept. Agr., Bur. of Soils (1904), No. 24, 9 and 20.

position, as determined in the moist state."²⁰ That this deduction is in error is shown by the data of Table XIV.

TABLE XIV.^a—*Effect of oven drying on the mechanical composition of soil.*

[Numbers give percentages.]

Soil.				Dried at 110°.						
Number.	Color.	Depth in cm.	Crop usually grown.	Moisture (H ₂ O).	Sand, 1.0 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, <0.002 mm.	Total including moisture.
1	Light brown loam.	0-15	Rice, corn	9.36	16.17	19.20	19.18	27.79	9.67	101.87
^a 1				8.19	14.83	13.99	23.35	30.21	9.57	100.14
2	Black ^d	0-15	Grass, rice	11.45	26.23	19.88	12.92	19.93	8.63	99.04
^a 2				11.75	25.12	18.24	9.59	24.62	9.88	99.20
3	Light brown	0-15	Rice	11.27	21.53	9.17	19.68	24.88	14.43	100.96
4	Brown clay	0-15	Rice, corn	12.10	17.92	14.81	15.75	26.46	14.26	101.30
5	Brown loam	0-15	Sugar cane, rice, corn.	10.56	20.19	18.89	14.95	25.69	10.29	100.57
6	Sticky clay	0-15	Rice, corn	10.80	33.10	14.59	9.88	23.11	8.43	99.91
7	Dark brown loam.	0-15	Tobacco, rice, corn.	8.85	24.85	22.32	9.01	26.89	9.68	101.60
8	Brown	0-15	Rice, corn ^e	10.17	29.15	19.05	8.69	21.08	12.78	100.92
^a 8				10.25	36.10	18.80	7.32	19.19	9.12	100.78
9	(^f)	15-30	do	14.46	49.83	14.13	6.79	9.94	5.66	100.81
^a 9				14.79	51.43	13.87	5.01	9.90	5.76	100.76
10	Dark brown	0-15	Sugar cane, rice, corn.	7.19	20.91	10.50	25.17	28.15	8.08	100.00
11	(^g)	15-30	do	15.32	34.31	13.93	16.50	11.79	8.15	101.83
^a 11				15.27	26.00	19.88	18.88	13.80	6.64	100.44
12	(^h)	30-60	do	17.97	27.62	23.07	17.05	8.83	5.17	99.71
^a 12				17.62	26.26	25.85	18.57	8.56	3.59	100.45
13	Dark loam	0-15	do	8.10	12.75	18.79	11.79	37.82	11.51	100.26
^a 13				7.83	12.09	19.79	11.57	38.43	10.99	100.70
14	Brown loam	0-15	Sugar cane ^e	8.07	21.30	20.24	8.72	32.52	10.20	101.05
^a 14				8.46	18.65	18.57	11.07	32.30	11.39	100.44
15	(ⁱ)	15-30	do	12.69	45.38	12.05	7.77	13.07	9.44	100.40
^a 15				12.72	44.00	14.03	8.83	14.33	11.47	100.38
16	(^j)	15-30	do	11.97	35.36	15.42	6.11	19.80	12.80	101.46
^a 16				11.59	37.03	13.38	10.29	18.12	10.19	100.60
17	(^k)	30-50	do	15.21	51.00	10.60	6.82	8.77	8.11	100.51
^a 17				15.32	52.21		7.28	8.08	7.14	

^a All clay percentages were obtained by direct determination.

^b Moisture separately determined.

^c Duplicate.

^d This soil is more than 1 meter deep and evidently contains soluble constituents.

^e Previous coffee.

^f Same location as No. 8.

^g Same location as No. 10. Consists of about 5 centimeters of surface and 10 centimeters of subsoil.

^h Subsoil of No. 10.

ⁱ Same location as No. 14. ^j True subsoil excluded from this sample.

^j Same location as No. 14.

^k Subsoil of No. 14.

TABLE XIV.^a—Effect of oven drying on the mechanical composition of soil—Contd.

Soil.				Air dried. ^b					
Number.	Color.	Depth in cm.	Crop usually grown.	Sand, 1.0 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, < 0.002 mm.	Total, including moisture. ^b
1	Light brown loam.	0-15	Rice, corn	14.10	12.90	20.05	29.96	14.02	100.39
c1				14.36	11.96	21.68	29.64	14.29	100.12
2	Black ^d	0-15	Grass, rice	24.15	15.64	10.97	25.35	12.16	99.58
c2							25.81	11.89	
3	Light brown	0-15	Rice	21.11	8.65	17.44	23.90	19.60	100.97
4	Brown clay	0-15	Rice, corn	9.98	10.43	9.28	32.20	27.10	101.09
5	Brown loam	0-15	Sugar cane, rice, corn.	13.27	13.71	17.24	31.01	15.46	101.25
6	Sticky clay	0-15	Rice, corn	29.63	9.40	13.51	25.75	11.29	100.38
7	Dark brown loam.	0-15	Tobacco, rice, corn.	17.75	16.55	13.56	32.94	11.91	101.56
8	Brown	0-15	Rice, corn ^e	26.75	13.38	10.62	23.78	15.28	99.98
c8				25.30	12.50	12.32	23.77	15.61	99.75
9	(f)	15-30	Rice, corn	22.66	9.05	10.52	22.58	20.74	100.01
c9				23.10	8.28	12.36	21.26	20.42	100.21
10	Dark brown	0-15	Sugar cane, rice, corn.	20.40	8.45	23.70	30.56	9.94	100.24
11	(g)	15-30	do	17.17	9.68	12.25	27.00	20.41	100.00
c11				17.52	9.82	12.41	26.62	18.80	100.47
12	(h)	30-60	do	23.52	6.57	10.05	17.96	23.85	99.92
c12									
13	Dark loam	0-15	do	13.77	18.17	12.32	37.20	10.18	99.74
c13				12.58	16.66	13.20	37.93	11.60	99.70
14	Brown loam	0-15	Sugar cane ^e	19.06	16.38	15.29	32.02	8.88	99.70
c14				18.73	15.44	14.48	34.05		
15	(i)	15-30	Sugar cane	23.06	7.87	10.88	27.27	18.39	100.16
c15				21.94	9.78	8.87	28.58	18.38	100.27
16	(j)	15-30	do	16.72	14.55	6.00	30.12	20.69	100.05
c16				15.58	12.74	8.13	32.26	20.99	101.29
17	(k)	30-50	do	14.00	7.63	10.45	26.03	27.23	100.55
c17				13.72	8.13	9.20	26.81	27.49	100.67

^a All clay percentages were obtained by direct determination.^b Moisture separately determined.^c Duplicate.^d This soil is more than 1 meter deep and evidently contains soluble constituents.^e Previous coffee.^f Same location as No. 8.^g Same location as No. 10. Consists of about 5 centimeters of surface and 10 centimeters of subsoil.^h Subsoil of No. 10.ⁱ Same location as No. 14. True subsoil excluded from this sample.^j Same location as No. 14.^k Subsoil of No. 14.

A comparison of the relative percentages of mechanical separates given in the above table shows that less of the finer grades and more of the coarser grades are obtained when the sample has been dried at 110°. In some cases the variation

is wide. That the error is of the same order of magnitude regardless of the method employed is shown in Table XV.

TABLE XV.^a—*Effect of oven drying on the mechanical composition of soils.*—
Continued.

[Numbers give percentages.]

Soil.			Air-dried. ^b					Dried at 110°.				
Num- ber.	Color.	Depth.	Sand.	Very fine sand.	Silt.	Clay.	Total.	Sand.	Very fine sand.	Silt.	Clay.	Total.
10	Dark brown	<i>Cm.</i> 0-15	5.75	4.82	35.76	54.27	100.60	8.57	12.86	54.48	24.71	100.62
11	(^c)	15-30	7.28	6.43	33.41	53.89	101.01	6.98	19.45	52.94	21.45	100.82

^a Analyzed by A. S. Arguelles. All clay percentages were obtained by direct determination.

^b Moisture separately determined and the results calculated to the dry basis.

^c Subsoil of No. 10.

The above analyses were made simultaneously by the centrifugal method.²⁰ There was no attempt to have the size of the smaller grains in the different fractions exactly conform to a given dimension, but rather to make them directly comparable. It was thought that perhaps this could be more accurately done if the samples were centrifugated each time for a definite number of minutes rather than controlled by the use of a micrometer microscope, and this method was used. The apparent clay in the two soils is reduced over 30 per cent by drying at 110°.

In all of the samples the analyses of which are recorded in Tables XIV and XV there is a great tendency for the oven-dried soil to form hard aggregates which do not disintegrate and in this way to step up the percentages of the coarser grains. This tendency is greatest for those soils containing the highest percentage of clay. A. V. Bleininger²¹ found that clays dried to 150° were found to show an extraordinary tendency to form hard aggregate particles and for the clays to become coarser grained. "The difference between the normal and the preheated clays, therefore, is due to coagulation; the material has become 'set', to use the language of colloid investigators, and irreversible as far as practical purposes are concerned." Bleininger²² found, in 16 hours' soaking after heating, that the general plasticity did not return and suggests heating as a practicable method for correcting excessively colloidal clays. Therefore, it is evident that mechanical analyses of oven-dried soils are not comparable since even duplicate analyses of a clayey soil do not agree. The analysis must be made without previous drying above ordinary temperatures.

The degree of accuracy which may be obtained with the modified Schöne apparatus on an air-dried soil disintegrated by shaking is shown not only by the duplicate results of Tables XIII and XIV, but also by the following four consecutive analyses of an air-dried soil made at widely separated times.

²⁰ *Bull. U. S. Dept. Agri., Bur. of Soils, loc. cit.*

²¹ *Trans. Am. Ceram. Soc.* (1909), 12, 504.

²² *Trans. Am. Ceram. Soc.* (1910), 11, 392.

TABLE XVI.^a—*Mechanical analyses of the same air-dried dark loam surface soil No. 13 by the modified Schöne method.*

Moisture	Sand.	Very fine.	Silt.	Fine.	Clay.
15.21	14.00	7.63	10.45	26.03	27.23
15.32	13.72	8.13	9.20	26.81	27.49
15.52	13.75	9.55	8.82	25.49	27.39
15.21	13.42	7.67	10.95	25.32	28.09

^a All clay determinations were made by direct determination.

The above discrepancies also include those of sampling as each sample was independently quartered from the stock bottle.

Analyses by this method are given in Table XVII.

TABLE XVII.—*Mechanical analyses of Philippine soils by the modified Schöne method.*

[Numbers give percentages.]

Number.	Specimen of soil.	Detritus not passing 1 mm. sieve.	Fine earth, water free basis.							Source.	Remarks.
			Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Finesand, 0.25 to 0.10 mm.	Very finesand, 0.10 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, <0.002 mm.		
3	0-30 cm.	6.92	3.88	6.40	19.48	16.27	15.37	25.53	13.07	Bokod, Benguet, Mountain Province.	Cf. corresponding numbers, Table I.
4	do	0.00	1.01	6.75	16.37	20.26	6.42	33.86	15.33	Daklan, Benguet, Mountain Province.	
5	do	0.00	1.16	4.04	8.00	7.88	8.97	42.17	27.78	do	
6	do	1.02	4.11	7.17	18.72	13.44	13.62	26.38	16.56	do	
7	do	(^a)	3.50	5.75	16.36	15.05	9.75	31.32	18.27	Updas, ^b Benguet, Mountain Province.	
8	do	(^a)	3.99	2.29	27.74	15.35	11.27	26.99	12.37	Bakung, ^b Benguet, Mountain Province.	
9	do	2.75	3.31	6.53	19.48	16.20	16.46	26.81	11.21	Lutab, ^b Benguet, Mountain Province.	
10	do	7.89	4.10	7.17	18.72	13.45	13.64	26.37	16.55	Lutab, ^c Benguet, Mountain Province.	
11	do	3.76	4.77	8.46	17.11	11.90	14.27	31.01	12.48	Cabayan, ^d Benguet, Mountain Province.	
12	do	5.57	2.59	4.11	15.76	18.76	20.77	28.53	9.48	Cusarang, ^e Benguet, Mountain Province.	
13	do	11.10	2.77	0.66	24.79	16.76	17.79	27.40	9.83	Cusarang, ^f Benguet, Mountain Province.	

TABLE XVII.—*Mechanical analyses of Philippine soils by the modified Schöne method—Continued.*

Number.	Specimen of soil.	Detritus not passing 1 mm. sieve.	Fine earth, water free basis.							Source.	Remarks.
			Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.10 mm.	Very finesand, 0.10 to 0.05 mm.	Silt, 0.05 to 0.01 mm.	Fine silt, 0.01 to 0.002 mm.	Clay, <0.002 mm.		
64	Surface.	0.48	1.10	2.85	10.01	7.46	15.32	28.07	35.19	Near Alabang, Rizal.	Planted to sugar cane. ^g
65	Subsoil.	0.66	1.24	2.85	7.62	7.28	11.82	31.57	37.62	do	
66	Surface.	1.54	1.02	2.44	10.88	9.71	11.70	28.78	35.46	do	
67	Subsoil.	2.26	1.84	2.62	8.64	9.52	8.47	28.08	41.33	do	
68	Surface.	0.91	1.96	4.30	12.63	10.41	11.32	28.80	30.59	do	
69	Subsoil.	0.55	1.12	2.49	8.56	10.34	8.41	31.58	37.50	do	
70	Surface.	1.20	1.75	3.11	11.60	10.35	13.04	29.60	30.55	do	
71	Subsoil.	0.97	1.42	2.64	9.87	9.06	10.13	30.28	36.60	do	
72	Surface.	0.82	1.38	3.05	10.18	10.26	8.62	31.32	35.19	do	
73	Subsoil.	0.52	1.55	2.97	9.05	8.85	7.27	31.10	39.21	do	

^a This soil is variable. In places it contains a high percentage of detritus some of which is very large.

^b See Plate I, figs. 1 and 2.

^c See Plate I, fig. 3.

^d See Plate II, fig. 1.

^e See Plate II, fig. 2.

^f See Plate III, fig. 1.

^g Cf. corresponding numbers, Table I.

The final weighings in these determinations were mostly made by Mr. A. S. Arguelles.

APPENDIX.

DIRECTIONS FOR TAKING SOIL SAMPLES.²³

Make a general inspection of the region, and select a representative field, i. e., one free from any modifications due to local conditions such as erosion, washing, etc. Inside the tract to be sampled, select five or six representative places, some distance from houses, fences, roads or trees and in cultivated fields midway between two plants, remove the surface accumulations of grass, leaves, or litter, and take samples with a soil tube or auger. A spade may be used if precautions are taken to dig a hole, one wall of which is smooth and perpendicular, to the proper depth and take the sample of soil from the side of the hole in a slice about 8 or 10 centimeters thick. Avoid mixing the layers of different depths. The sampling should be done preferably when the soil is reasonably dry, after the crop has been harvested and before fertilization.

Surface soil.—Sample each of the five or six spots chosen to a depth of 15 centimeters (6 inches) or to the change between the surface soil and subsoil, in case such change occurs between the depth of 15 and 30

²³ Conforming as far as practicable to methods in use in the United States and elsewhere. Cf. *Bull. U. S. Dep. Agr., Bur. of Chem.* (1908) 107 (revised), 13.

centimeters, and place these together as representing the *surface soil*. *In no case is the sample to be taken to a greater depth than 30 centimeters (12 inches).*

If the surface soil extends to a greater depth than 30 centimeters, take a separate sample below the depth of 30 centimeters to a change between the surface soil and the subsoil, or to a depth of a meter if no change occurs. This sample of the *subsurface soil* should be obtained in other respects precisely like that of the surface soil.

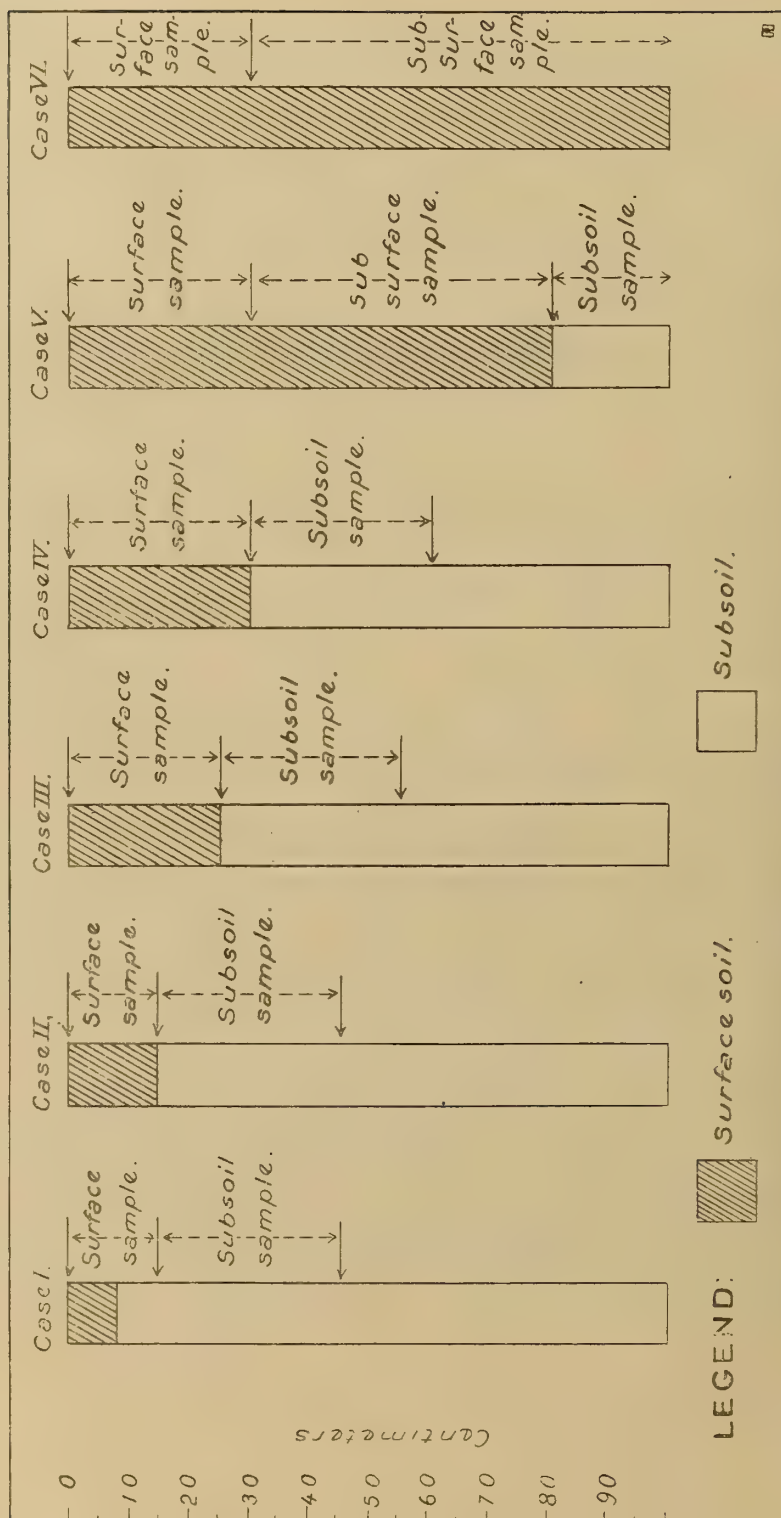
Subsoil. The depth to which the sample of subsoil should be taken will depend on circumstances. It is always necessary to know what constitutes the foundation of a soil to the depth of 1 meter at least, but in ordinary cases 25 or 30 centimeters will be sufficient for examination in the laboratory and should be taken in precisely the same manner as the surface soil.

If the surface soil extends to a considerable depth below 30 centimeters, the sample of subsoil may be taken with less exactness, perhaps at some ditch or other accessible point, and its physical characteristics noted, i. e., whether a clay, rock, sand, etc.

Combine the borings of a given depth. Empty these large composite samples in turn upon canvas, oilcloth blanket, large heavy paper, or floor so as to protect the sample as much as possible. Break all lumps and mix thoroughly. Divide the sample by "quartering" and discard the two diagonally opposite quarters; mix the remainder and again quarter, repeat the process until only about $1\frac{1}{2}$ to 2 kilograms are left, and place in cans or in tight canvas or muslin sacks for the laboratory.

Each sample should have duplicate labels, one to be placed inside the bag and the other to be tied on the outside. A number may be marked on the bag and a descriptive letter prepared, but the label to be placed within the bag should, under no circumstances, be omitted. This process of taking samples may be modified as the exigencies of the work necessitate, but only those taken as above will be entirely satisfactory. Any departure from this method of sampling should be carefully noted.

Describe accurately the location of the field from which the sample is taken and the actual depth represented by each sample. It is often desirable to relocate a field and repeat the analyses after the fields are under irrigation or have been cropped for a long time. Add any statistics regarding the land as to crops, years under cultivation or since cultivation, etc., or any topographical information which is easily available. The above directions for taking soil samples are represented graphically in fig. 10.



Directions for taking soil sample represented graphically.

ILLUSTRATIONS.

PLATE I.

- FIG. 1. Looking across the Agno River Valley from Updas to the *presidencia* at Lutab, Benguet, Mountain Province. Bakung in the distance to the right. Cf. soils Nos. 7-9, pp. 303, 325. (Photograph by Beyer.)
2. Looking across the Agno River Valley from the *presidencia* at Lutab to the coffee groves and towns of Bakung on the right and Updas on the left. Cf. soils Nos. 7-9, pp. 303, 325. (Photograph by Beyer.)
3. Looking up the Agno River. The first group of terraces north of Cabayan *presidencia* at Lutab in the foreground, and coffee trees in the background. Cf. soil No. 10, pp. 303, 325. (Photograph by Beyer.)

PLATE II.

- FIG. 1. Looking up the Agno River showing the second group of terraces north of Lutab. Cf. soil No. 11, pp. 303, 325. (Photograph by Beyer.)
2. The large group of terraces at Cusarang, Benguet. Cf. soil No. 12, pp. 304, 325. (Photograph by Beyer.)

PLATE III.

- FIG. 1. The first group of terraces north of Cusarang. Cf. soil No. 13, pp. 304, 325. (Photograph by Beyer.)
2. Camote field. Arrival of the party of the Secretary of the Interior, Bagnin, Lepanto, 1909. (Photograph by Martin.)

PLATE IV.

- FIG. 1. Benguet pine, (*Pinus insularis* Endl.) Baguio. Stand of fifteen, seventeen and one-half, and twenty centimeter pines. (Photograph by Bureau of Education.)
2. Botanical garden, Manila. (Photograph by Martin.)

PLATE V.

- FIG. 1. Cutting and stacking *zacate*, (*Leersia hexandra* Sw.) Manila. (Photograph by Bureau of Agriculture.)
2. Guinea grass, (*Panicum maximum* Jacq.) Singalong farm, Manila. (Photograph by Martin.)

PLATE VI.

- FIG. 1. Maguey (*Agave* sp.) in bloom, Singalong farm, Manila. (Photograph by Bureau of Agriculture.)
2. Papaya (*Carica papaya* Linn.) tree in fruit, Singalong farm, Manila. (Photograph by Martin.)

PLATE VII.

- FIG. 1. Rubber tree, (*Hevea brasiliensis* Muell.-Arg.) Singalong farm, Manila. (Photograph by Martin.)
 2. Liberian coffee, (*Coffea liberica* Hiern) Lamao, Bataan. (Photograph by Bureau of Agriculture.)

PLATE VIII.

- FIG. 1. Banana field, Lamao Bataan. (Photograph by Cortez.)
 2. Lamao forest ridge, Mountain Mariveles, Bataan. (Photograph by Cortez.)

PLATE IX.

- FIG. 1. Irrigated rice, Alabang, Rizal. (Photograph by Bureau of Agriculture.)
 2. Cutting sugar cane, *hacienda* Lumañgub, Bago, Negros Occidental. (Photograph by Walker.)

PLATE X.

- FIG. 1. Coconuts in fruit, San Ramon farm, Mindanao. Note the large number of nuts. (Photograph by Martin.)
 2. Hemp, (*Musa textilis* Née. La Carlota, Negros Occidental. (Photograph by Bureau of Agriculture.)

PLATE XI.

- FIG. 1. Cultivating tobacco, Ilagan, Isabela. (Photograph by Bureau of Education.)
 2. Tobacco seed selection, Ilagan, Isabela. (Photograph by Bureau of Education.)

TEXT FIGURES.

- FIG. 1. Normal duration of sunshine in Manila 1890 to 1907.
 2. Normal evaporation, 1885 to 1907, Manila.
 3. Map showing two definite types of rainfall in the Philippines.
 4. Mean rainfall in the western portion of the Philippine Archipelago.
 5. Mean rainfall in the eastern portion of the Philippine Archipelago.
 6. Mean rainfall in Surigao.
 7. Map showing by provinces the per cent of the total area under cultivation devoted to the cultivation of coconuts, hemp, and tobacco in the Philippine Archipelago.
 8. Modified Schöne apparatus for the mechanical analysis of soils.
 9. Detail picture of the outflow-tube and piezometer.
 10. Directions for taking soil sample represented graphically.



Fig. 1. THE AGNO RIVER VALLEY FROM UPDAS.

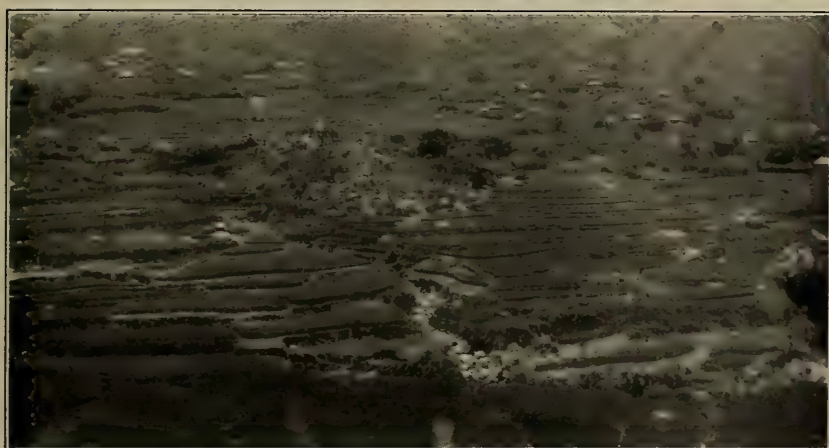


Fig. 2. VIEW FROM THE "PRESIDENCIA" AT LUTAB.

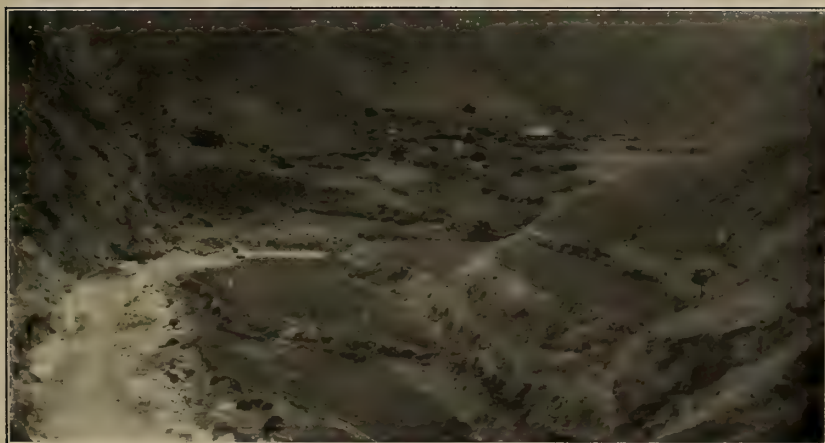


Fig. 3. TERRACES, AGNO RIVER, NORTH OF LUTAB.

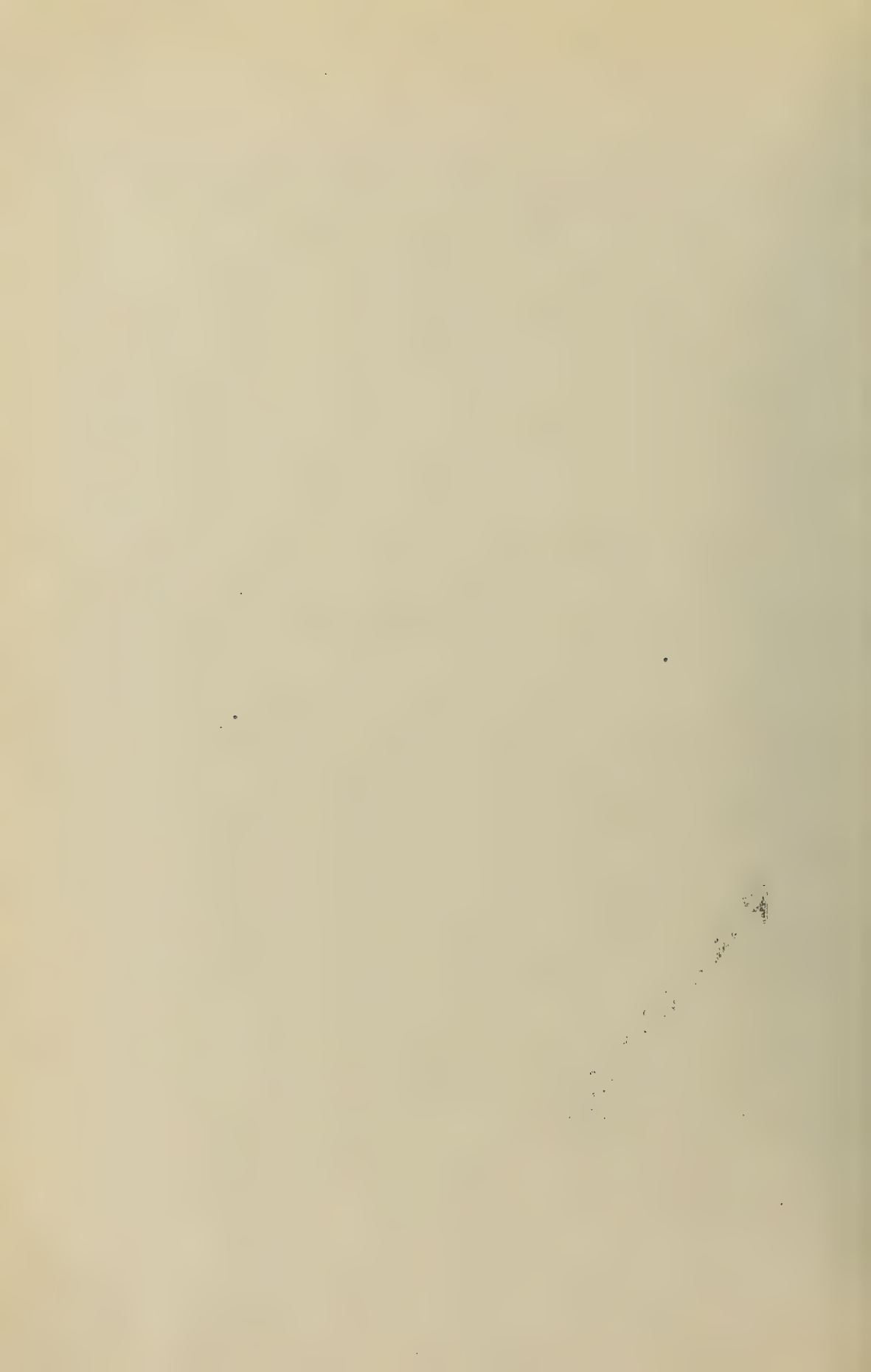




Fig. 1. TERRACES, AGNO RIVER, NORTH OF LUTAB.

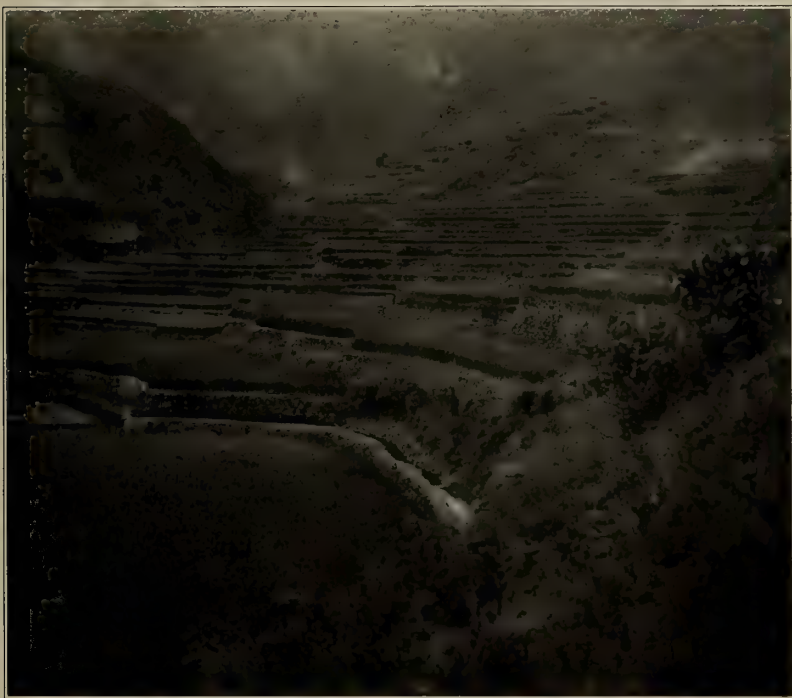


Fig. 2. TERRACES AT CUSARANG, BENGUET.

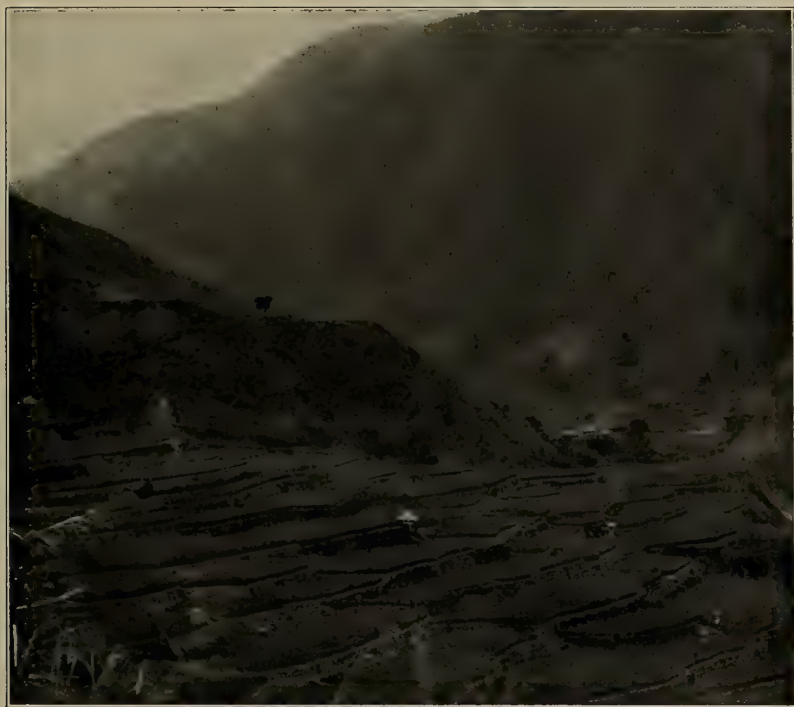


Fig. 1. TERRACES NORTH OF CUSARANG.



Fig. 2. CAMOTE FIELD, BAGNIN, LEPANTO.

PLATE III.



Fig. 1. PINE (*Pinus insularis* Endl.), BAGUIO.



Fig. 2. BOTANICAL GARDEN, MANILA.





Fig. 1. ZACATE (*Leersia hexandra* Sw.), MANILA.



Fig. 2. GUINEA GRASS (*Panicum maximum* Jacq.), MANILA.



FIG. 1. MAGUEY (SISAL HEMP) IN BLOOM, MANILA.



FIG. 2. PAPAYA IN FRUIT, MANILA.



FIG. 1. PARA RUBBER TREE, MANILA.



FIG. 2. LIBERIAN COFFEE, BATAAN.



Fig. 1. BANANA FIELD, BATAAN.



Fig. 2. FORESTED RIDGE, MOUNT MARIVELES.



Fig. 1. IRRIGATED RICE, ALABANG, RIZAL.



Fig. 2. SUGAR CANE, NEGROS.

PLATE IX.



Fig. 1. COCONUTS, MINDANAO.



Fig. 2. MANILA HEMP (ABACA), NEGROS.

PLATE X.



Fig. 1. CULTIVATING TOBACCO, ISABELA.



Fig. 2. TOBACCO SEED SELECTION, ISABELA.

A THEORY ON THE FORMATION OF THE CENTRAL LUZON PLAIN.

By RAF. HERRMANN.

(*Manila, P. I.*)

Professor Suess, in his work, "The Face of the Earth," compares the Philippines to an open fan. The handle is formed by northern Luzon and the ribs widen out toward the south. There are several lines of ranges distinctly marked by islands. The most western starts from North Borneo and reaches through Palawan, the western point of Mindoro, and the Province of Zambales on Luzon; next follows a line along which is arranged eastern Borneo, the Sulu Archipelago, western Mindanao, Negros, and Masbate; then central Mindanao, Leyte, and Masbate; the fourth strikes from eastern Mindanao, Samar, and southern Luzon to the central Luzon ranges; and the last can be traced from Catanduanes, Camarines, and Polillo, to the east coast of northern Luzon.

The formation is very similar to the Alpine system in Europe, where we have the parallel to northern Luzon in the western part. The first chain to separate is that of the Appenines through Italy, then follow the Dinaric chains through Turkey, farther north two small ranges, the Ivans Cica and the Hungarian Mountains, and the last ones are the Carpathian Mountains. At the separation of the Alpine ranges is the Vienna basin, a nearly circular sunken piece of ground, which in the Philippine Islands is represented on a much larger scale by the Sulu Sea with the following boundaries: To the westward, Palawan; to the southward, Borneo, and the Sulu Archipelago; to the eastward, Mindanao and Panay; to the northward, Mindoro.

All the afore-mentioned ranges spread out toward the south, approach each other toward the north, and form a solid mountain massif from east to west in northern Luzon, interrupted only by the long erosion valley of the Cagayan River. It appears all the more strange to me from a geological point of view in that at the Gulf of Lingayen these mountains suddenly break off and we find the central Luzon plain between the mountains of Zambales to the westward and the central ranges to the eastward. It attracts my attention still more, because the Island of Mindoro lies in front of the central plain to the southward like a barrier. If this were

not so, we could adopt the idea that in the same way in which Cebu and Negros form a syncline, which is proved by the coal seams on both islands, the mountains of Zambales and the central ranges form a similar syncline, which in no way is proved and does not agree with the sudden disappearance of the depression to the northward and to the southward.

A profile through Zambales, the central plain, and central Luzon ranges, gives the following view:

Zambales: mountainous, gabbro serpentine, talcose schists. Central plain: alluvial, volcanic tuffs.

In the plain: Mount Arayat a basaltic extinct volcano.

The central ranges: Tertiary limestone and sandstone interrupted by volcanic intrusions.

In my opinion this tectonic structure can best be explained by a trench break between the Zambales and central mountains. When the ranges were formed during the Tertiary period, the northern Luzon mountains had their continuation right through the central plain, and reaching over to Mindoro, formed one solid mountain massif from Zambales to the east coast. Thereafter on parallel fissures the central part slid down and probably there was a time when Zambales was an island and the sea reached from Manila Bay to the Gulf of Lingayen. Volcanic eruptions accompanied the displacement, strong and still active in the southern part (Taal Volcano), weak and extinct in the interior (Arayat).

The upheaval which lifted the whole western coast of Luzon out of the sea also laid the central plain dry and the two bays to the northward and to the southward are the remnants of the former connection.

If we look for a similar occurrence in other parts of the world, we find one in the Rhine Valley between the Vosges and the Black Forest. Here we have on both sides old granite and gneiss formations; leaning against them, and broken off in steps, lie sediments; and between the two ranges is the valley, with diluvial and alluvial deposits. Like Arayat, the Kaiserstuhl, a volcanic mountain, rises from the plain abruptly and without apparent connection with its surroundings. To prove this theory a careful study of the boundary line between the plain and the mountains will be required. If we find the youngest sediment beds along this line dipping from east, north and west toward the plain, and if we find them rising not regularly but in steps separated by fissures from each other, we can safely say that this theory is well founded and corresponds with the facts in the field.

NEW PHILIPPINE ESSENTIAL OILS.

By BENJAMIN T. BROOKS.

(From the Laboratory of Organic Chemistry, Bureau of Science, Manila, P. I.)

INTRODUCTION.

Ylang-ylang oil, extracted from *Canangium odoratum* (L.) Baill., is the only essential oil at the present time exported from the Philippines in large quantities. However, the researches of R. F. Bacon,¹ carried out in the chemical laboratory of the Bureau of Science have shown that other essential oils undoubtedly can profitably be produced in these Islands. The absence of a suitable botanical garden, where data on the cultivation of plants yielding essential oils can be obtained, is a serious handicap to more extended investigations in this line. Many data, necessary as they are from a commercial standpoint, are not to be had in many cases, or else the desired information has been obtained by private individuals at their own expense.

The present paper contributes some information concerning certain new essential oils and several others, well known, which, until now, have not been reported from the Philippines.

THE ESSENTIAL OIL OF MICHELIA CHAMPACA L.

Michelia champaca L. is cultivated either from seeds or cuttings. It appears to require very careful attention. However, Mr. John C. Mehan, of the department of streets and parks of the city of Manila, has grown both seeds and cuttings with great success. If grown from seed, the plants should be sprouted in sand, otherwise there is great danger that the seeds may rot. Mr. Mehan has successfully raised over 90 per cent of the cuttings from this variety. It also seems inadvisable to transplant the seedlings, according to the experience of Mr. George Worcester, of Cabanatuan. The method of marcottage, which is very successful in the case of white champaca, *Michelia longifolia* Bl., does not appear to give satisfactory results with the species in question.

The flowering season during the year 1910 lasted from about the middle of June until the latter part of October. This season probably was prolonged slightly, owing to the comparative scarcity of rains during this time, which ordinarily is the period of heavy rainfall.

In a recent bulletin of the firm of Roure-Bertrand Fils,² it is stated that

¹ *This Journal*, Sec. A (1908), 3, 49, 65; (1909), 4, 93; (1910), 5, 257.

² Bulletin of Roure-Bertrand Fils (1909), 1, 26.

Michelia champaca L. is a tree of such a size that a man can scarcely encircle the trunk with his arms. This does not appear to be the case in the Philippines. The trees about Manila are usually somewhat smaller than those of ylang-ylang and have trunks which are 20 to 50 centimeters in diameter. The above firm also states: "According to our observations, the perfume of the flowers of the Philippine champaca is stronger and sweeter than that of the Singapore, Penang, Colombo, and Peradiniya flowers. It would appear that it is the same with this tree as with the ylang-ylang, which does not yield the same essential oil in Java, the Straits, or Ceylon as in the Philippines."

The Royal Botanical Gardens at Peradiniya, Ceylon, contain *Michelia champaca* trees which are from 1 to 1.25 meters in diameter, and Mr. F. A. McMillan, the curator, states that he has seen one felled which was at least 2 meters in diameter. Many trees growing at Peradiniya are much larger than those in the Philippines. Ylang-ylang and kapok trees attain fully twice the size they ordinarily reach in this Archipelago.

In experimenting with champaca flowers it is essential to work rapidly as after they have been picked a few hours they begin to turn brown and their fragrance is seriously impaired. The rapidity with which this darkening takes place when the flowers are slightly bruised recalls the similar behavior of gardenia flowers, which contain an oxidizing ferment.

I have found that an oxidizing ferment is present in champaca flowers, and the change in color and deterioration of the fragrance is accompanied by oxidation. However, the development of the color may take place slowly after the enzyme is killed or inhibited by certain poisons. The autoxidation of a chromogen substance evidently occurs.

An aqueous solution of the oxidase turns tincture of guaiacum blue directly and oxidizes certain phenols. The solution turns brown at the surface the instant it is exposed to the air, but previous heating for a few minutes to 100° will prevent the coloration.

It is possible that this oxidase has something to do with the development of the disagreeable odor in the brown flowers.

The constants of two specimens of champaca oil recently prepared here are as follows:

Constants.	Specimen No.-	
	I.	II.
Specific gravity $\frac{30^{\circ}}{30^{\circ}}$ -----	0.904	0.9107
Refractive index N $\frac{30^{\circ}}{D}$ -----	1.4640	1.4688
Ester number -----	124	146
Ester number after acetylating -----		199

THE CONSTITUENTS OF THE OIL OF MICHELIA CHAMPACA L.

Concerning the constituents of champaca oil Bacon³ recently has shown that 3 per cent of the oil consists of iso-eugenol. Schimmel and Company⁴ report benzoic acid as occurring in champaca oil whereas Bacon did not find this substance in the sample examined by him. The former also state that the odor of the oil is somewhat suggestive of cassie flowers. I have found benzoic acid in the oil prepared by me, but only in small amounts, probably not exceeding one-half of one per cent. The odor, in my opinion, is somewhat suggestive of cassie flowers, particularly after some of the more volatile constituents are lost by evaporation. However, Schimmel and Company state that about 60 per cent of the sample of champaca oil examined by them in 1907⁵ consisted of linalool, which certainly is not true of the oil prepared here.

The presence of aldehydes or ketones in champaca oil, together with the energetic oxidase which I have shown is present, is particularly interesting in view of the theories regarding the formation of essential oils and the changes undergone by them during the development of the plant. Thus, the crystalline substance which separates from the essence concrete is a ketone, and I have shown that benzyl alcohol, benzaldehyde, and benzoic acid are present in the oil. Inasmuch as the aldehydes constitute 6 per cent of the oil, it is quite probable that the small amount of benzoic acid found is derived directly from benzaldehyde by oxidation. The tendency of benzyl alcohol to form benzaldehyde by oxidation in the air is well known and these two substances are often associated in essential oils. The oxidation of benzyl alcohol or any similar compound undoubtedly would be much accelerated by an oxidase such as occurs in champaca.

When a few drops of champaca oil are shaken up with a little hot water, a very marked camphor-like odor may be noticed. This odor is due to cineol which is one of the constituents which gives to champaca oil its character.

Heat causes the polymerization of a large part of champaca oil to a resin. This is particularly noticeable when the oil is saponified with alcoholic caustic potash. The previous removal of aldehydes reduces the tendency to form resins. Although the essence concrete of cassie flowers may be distilled with steam, champaca oil when so treated yields a distillate having an odor entirely different from the original material. A large part of the oil is converted into resin.

Experimental.—When it is attempted to distil champaca oil *in vacuo*, most of the oil polymerizes to a resin.

³ *This Journal, Sec. A* (1910), 5, 262.

⁴ *Semiannual Rep.* (1897), 1, 11.

⁵ *Ibid.* (1907), 2, 33.

Fifteen grams of oil were distilled at 13 millimeters pressure. Up to 190° only 4.5 grams of distillate were obtained. This was collected in four fractions, but these fractions were not investigated as a large part of the sample had polymerized.

The oil obtained by distilling it with steam consists largely of cineol. Twenty-five grams of oil yielded about 6 grams of distillate which smelled strongly of cineol and also of *p*-cresol methyl ether. The latter substance as yet has not been identified in this oil. Methyl salicylate, which has a somewhat similar odor, is not present.

Saponification of the oil with alcoholic caustic potash, distillation of the alcohol, and distillation of the remainder with steam, yields a distillate amounting approximately to 25 per cent of the original oil. This distillate consists largely of cineol as the fraction boiling from 172° to 178° on treatment with iodol gave the double compound melting at 112° to 114°, which is characteristic of cineol. No other compounds have been identified in these fractions.

Fifty grams of champaca oil were shaken with a concentrated solution of sodium acid sulphite. On adding sodium carbonate to the sulphite solution and extracting with ether, 3.0 grams of oil were obtained which smelled strongly of benzaldehyde. A semicarbazone was prepared which melted at 195° to 200°, not sharp, and a phenyl-hydrazone which after recrystallizing from dilute alcohol melted at 149° to 151°. Benzaldehyde, therefore, is present, but another substance also is present which has not been identified.

One hundred grams of the oil were dissolved in alcohol and precipitated in fractions, by the addition of water. The first fractions contained most of the cineol. The last fractions to be separated in this manner had an altogether different odor from the first. Finally, extraction of the aqueous alcoholic solution with chloroform yielded a heavy oil which contained benzyl alcohol. The presence of benzyl alcohol was shown by shaking out with sodium acid sulphite in order to remove any aldehydes present and then oxidizing 0.5 cubic centimeter of the oil with chromic acid mixture. On distilling with steam and adding one drop of phenylhydrazine to the distillate, benzaldehyde phenyl-hydrazone was obtained, which, after recrystallizing from dilute alcohol, melted at 153° to 154°.

Saponification of 10 grams of the last fraction precipitated by water yielded 1.6 grams of an acid tar, which, on boiling with water, yielded 0.3 gram of benzoic acid crystals, melting sharply at 120°. The melting point was unchanged when the substance was melted with pure benzoic acid.

No acids other than benzoic acid have as yet been identified. Acetic or formic acid is not present.

Fifty grams of oil were saponified in the usual manner, and after the neutral and phenolic constituents had been removed the solution was acidified and extracted five times with ether. The solution was then distilled with steam until one-third of it had passed over. This solution required only 1.2 cubic centimeters of $\frac{10}{N}$ caustic soda for neutralization.

The ether extract contained considerable resin. After purifying with dilute alcohol the acid was obtained as a pungent-smelling oil, very sparingly soluble in water. It has not yet been identified.

THE CRYSTALLINE SUBSTANCE CONTAINED IN YELLOW CHAMPACA FLOWERS.

Since comparatively large amounts of a crystalline substance is contained in champaca flowers, it was thought advisable to investigate the nature of this substance.

If the substance is sufficiently purified by repeated crystallization from chloroform and ligroin, it finally is obtained as colorless crystals entirely without odor. By recrystallizing the substance in the cold, no trouble was experienced and the amorphous product encountered by Bacon⁶ was not obtained during the process of purification. According to Bacon, the empirical formula of the compound is $C_{16}H_{20}O_5$.

The substance is laevorotatory. A specimen weighing 1.0 gram, dissolved in 15 cubic centimeters of chloroform, gave a rotation, in a 10-centimeter tube, of -5.5° .

As described by Bacon,⁷ the substance "shows a tendency to soften at 165° , and melts with decomposition at 338° ." I have found that even after the most careful purification the behavior of the body in this respect is always the same. If two compounds which possess melting points so far apart are present in a mixture, it should be possible to separate them by crystallization from the proper solvents. Repeated crystallization from various solvent mixtures failed to indicate any such separation. The crystals always melted at from 165° to 166° but never gave a clear liquid. Further heating caused the substance to char at about 335° to 340° .

Under the microscope the crystals are all identical in character. Those deposited by the spontaneous evaporation of an alcoholic solution were symmetrical, diamond-shaped plates possessing two extinctions parallel to the two axes of symmetry. Therefore, they are probably monoclinic. The acute angles of the plates are 64° . A chloroform solution sometimes yields six-sided plates, while the crystals precipitated from chloroform by ligroin are like those grown in alcohol.

The following experiments make it very probable that the substance is homogeneous:

A single large crystal, formed by the spontaneous evaporation of an alcoholic solution, was pulverized and its melting point determined. It melted at from 165° to 166° to a lumpy, sticky mass after the usual manner. Further heating caused decomposition at about 340° .

Believing that this behavior on melting was due to the polymerization of the pure substance by heat, the following experiment was undertaken:

About 0.3 gram of the substance completely soluble in chloroform, was heated in a test tube immersed in an oil bath, at 170° , until it softened. Part

⁶ *This Journal*, Sec. A (1910), 5, 264.

⁷ *Loc. cit.*

of the specimen passed quickly into solution on the addition of chloroform, but there remained a large amount of white, amorphous, flocculent substance resembling the insoluble amorphous compound often obtained by heating a solution of the crystals. This chloroform solution deposited crystals on the addition of ligroin which were identical with the original substance.

The conclusion that the crystalline substance undergoes polymerization when heated, either alone or in solution, yielding the amorphous, insoluble compound, appears to be justified. The behavior of the compound toward sodium acid sulphite supports the conclusion that one substance only is present originally. I have found that, contrary to the experiment described by Bacon, the crystalline substance reacts quantitatively with sodium acid sulphite.

Twenty grams of the substance were dissolved in a mixture of alcohol and benzene and vigorously shaken in a shaking machine for four hours with a concentrated solution of sodium acid sulphite. On working up the reaction mixture, the benzene solution on spontaneous evaporation gave 0.2 gram of amorphous substance which apparently was identical with the polymerization product. The original material therefore had passed practically quantitatively into the aqueous acid sulphite layer. On treating the aqueous solution with sodium carbonate in the usual manner, nothing separated, nor did any substance separate on warming a small portion of the mixture.

Sodium hydroxide failed to precipitate anything from another small test portion. The solution was extracted with chloroform before and after making alkaline, but with no result. The aqueous-alcoholic solution was then gently evaporated on the steam bath. When quite concentrated, an oily layer was salted out which was separated from the remaining solution. This viscous, syrupy substance was exceedingly soluble in water. On standing *in vacuo* over sulphuric acid the mass slowly crystallized. Ignition of a small fragment on a platinum spatula showed it to be largely organic, the substance burning vigorously with a smoky flame. The residue was sodium sulphate and sulphite. This exceedingly soluble and stable substance is evidently a compound of sodium acid sulphite with the whole or at least the ketone part of the original substance. Hydrochloric acid caused nothing to separate from concentrated solutions of the sodium compound. The aqueous solution, slightly acidified with acetic acid, gave no precipitate after the addition of sodium acetate and phenylhydrazine acetate.

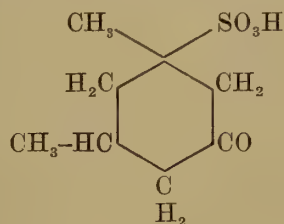
What apparently is the free acid, of which the sodium compound is the salt, was prepared by digesting a few grams of the salt on the steam bath with glacial acetic acid. Sulphur dioxide was evolved, and after the mixture was evaporated nearly to dryness it was extracted with chloroform. Addition of ligroin to the concentrated chloroform solution gave a very small yield of an oily substance, the physical properties of which were totally unlike that of the original material. This oil could not be made to crystallize.

Attempts to recrystallize the sodium salt from absolute or 95 per cent alcohol were without result.

A small amount of the sodium salt in solution was slowly concentrated with an approximately equivalent quantity of barium chloride. The crystals deposited proved to be only barium chloride.

The behavior of this ketone compound on treatment with sodium acid sulphite, and the impossibility of regenerating the original substance

from it, recalls the observations of Knoevenagel⁸ in regard to the group $\text{CH}=\text{CH}-\text{CO}$. Dimethyl cyclohexanone yields the acid,



a sulphonic acid radical remaining attached to carbon. Such compounds combine with two molecules of sodium acid sulphite.

That the substance is a ketone and not an aldehyde is indicated by its behavior toward ammoniacal silver nitrate and fuchsin sulphurous acid. The phenylhydrazone, described by Bacon as melting at from 153° to 155° , was prepared and after several crystallizations from hot alcohol melted sharply at 161° . I have found that the ketone reacts with one molecule only of phenylhydrazine, the resulting phenylhydrazone having the composition $\text{C}_{16}\text{H}_{20}\text{O}_4 : \text{N} \cdot \text{NH} \cdot \text{C}_6\text{H}_5$ as shown by the following analysis

0.2057 gram substance gave 14.2 cubic centimeters nitrogen, measured at 30° , and 760 millimeters.

Calculated for $\text{C}_{16}\text{H}_{20}\text{O}_4 = \text{N} \cdot \text{NH} \cdot \text{C}_6\text{H}_5$

N=7.33

Found,
per cent.

7.48

Hanus' solution of iodine in glacial acetic acid indicates only one double linking, although two and possibly three are present.

0.2035 gram substance absorbed 0.171 gram iodine.

Calculated for one double bond=0.176 gram iodine.

According to Thieles' theory of partial valences, the group $-\text{HC}=\text{CH}-\text{CO}$ is very reactive. This probably is the group attacked.

An alkaline solution of bromine, or hypobromite, gave bromoform, recognized by conversion into ordinary carbylamine by the addition of aniline.

The remaining four oxygen atoms are present in two carboxyl groups, since no evidence was adduced indicating a free hydroxyl group.

A small sample of the substances was heated to 100° for 3 hours with acetic anhydride, but the unchanged material was recovered. Acetyl chloride entirely decomposes the compound, yielding nothing but a tar.

After several unsuccessful trials it was found that a crystalline potassium salt could be produced on heating with an excess of a solution of caustic potash in absolute alcohol. This salt crystallizes from hot absolute alcohol in minute needles, often in feathery aggregates. The addition of potassium ethylate to the solution in absolute alcohol increased the yield of the recrystallized salt. It is exceedingly soluble in water. The lead salt, made by adding lead nitrate to

⁸ Ber. d. deutschen. Chem. Ges. (1904), 37, 4041.

a neutral solution of the potassium salt, is amorphous when first precipitated, but changes in a few hours to crystals. Under the microscope these crystals proved to be rhombic plates, the acute angles of which are approximately 72° . The substance decomposed with explosive violence when a combustion was attempted. Two lead determinations gave 65.2 and 65.4 per cent of lead. Neutral lead succinate contains, theoretically, 64.0 per cent of lead, but according to Beilstein⁹ the salt exhibits a tendency to precipitate with a slightly basic composition, which would account for the slight discrepancy between the calculated analysis and the results found. Lead succinate was made and its crystal angles compared with the salt under investigation. The corresponding angles were found to have the same values.

One-half gram of the original substance was treated with 5 cubic centimeters of alcohol and a small quantity of zinc chloride in hydrochloric acid. A few drops of an ester were obtained which possessed an odor apparently identical with that of diethyl succinate.

It seems evident that succinic acid is present in the original crystalline substance as a neutral ester. Therefore, if a carboxethyl group is assumed to be present, the remaining alcohol radical must contain 10 carbon atoms.

Therefore the compound was saponified by boiling with an excess of aqueous sodium hydroxide. Ten grams in 50 cubic centimeters of 5 per cent sodium hydroxide solution were slowly distilled until 10 cubic centimeters had passed over. This fraction possessed a strong odor, resembling that of carvol, or perhaps isoeugenol, and owing to the presence of this substance in the distillate the alcohol was not quantitatively determined. Its presence was qualitatively shown by the iodoform reaction, the latter compound being slowly formed at 30° and very quickly at 60° . The iodoform was recognized by its odor and the characteristic habit of the crystals.

Saponification of 2.0 grams of the compound with one-half the amount of caustic potash theoretically required, yielded an acid substance which on evaporation of its solution in ether gave a tough, resinous jelly which could not be redissolved.

Ten grams of the original compound were saponified at room temperature by an excess of aqueous caustic potash. After standing 48 hours, 1 gram of the original material was recovered by filtering and the alkaline filtrate extracted five times with ether. The ether extract yielded about 0.1 gram of an oil having an odor resembling that of carvol. A portion of the original solution was slightly acidified with acetic acid and treated with phenylhydrazine acetate. One-half of the resulting solution was gently heated on the steam bath and the other portion placed in the ice box. Neither yielded a precipitate. The remaining aqueous-alkaline solution was then acidified with sulphuric acid and extracted five times with ether and 1.0 gram viscous oil were obtained which gradually resinified.

The substance or substances resulting from the hydrolysis or saponification of the ketone, polymerize very readily, particularly in the presence of alkalies.

In one experiment the crystalline substance was saponified by heating for about 10 minutes to 60° with alcoholic caustic potash; the solution quickly cooled and the excess of potassium hydroxide neutralized by carbon dioxide. The

⁹ *Handbuch d. Organischen Chemie* (1893), 1, 654.

potassium carbonate was filtered with suction and the alcohol distilled *in vacuo* until almost all of it had passed over. On adding water and extracting with ether, no oil, but only a tar was obtained. The action of alkalies in promoting the formation of tar was also noticed when the substance was tested for alcohol, as described above. The first cubic centimeter of the distillate contained minute drops of an oil with an odor like that of carvone, but the alkaline solution very quickly darkened and oil drops ceased to pass over.

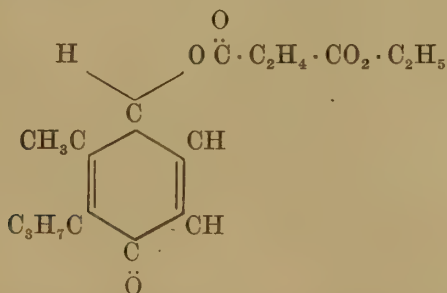
Because of the results noted above, several attempts were made to split the compound with dilute acids.

Three grams of the ketone were warmed to 60° with 50 cubic centimeters of 60 per cent alcohol containing 2 drops of concentrated sulphuric acid. After the crystals had dissolved, 0.2 gram of the polymerization substance were obtained by filtering. The solution was neutralized with sodium carbonate, sodium acetate added, and the whole divided into two portions which were treated respectively with phenylhydrazine acetate and semicarbazid hydrochloride. The first solution yielded less than 0.1 gram of a crystalline phenylhydrazone contaminated with tar, and the second deposited about the same amount of a semicarbazone which, when recrystallized from dilute alcohol, melted at from 186° to 187°. The quantity obtained was too small for analysis and the yield was so poor that the experiment was not repeated.

The few drops of oil resulting from the several saponification experiments were tested with phenylisocyanate and with 1, 3, 5-dinitrobenzoyl chloride, but no crystalline product was obtained.

It is clear from the foregoing results that the crystalline substance contains one ketone group, no free hydroxyl radicals, and one succinic acid group. One carboxyl group of the acid is combined as the ethyl ester and the other attached to a group which is probably a ketone alcohol of the formula $C_{10}H_{12}O_2$, the latter radical evidently containing the group $\cdot HC:CH \cdot C:O$.

These considerations suggest the constitution.



However, this representation does not agree with the empirical formula.

If, instead of an isopropyl group the group $\begin{array}{c} \text{CH}_2 \\ \parallel \\ -\text{C} \\ \backslash \\ \text{CH}_3 \end{array}$ is assumed to be present, all the conditions are satisfied. Further work will be necessary before this can be settled definitely.

THE OIL OF *MICHELIA LONGIFOLIA* BL.

Since champaca oils which were prepared from mixtures of the white and yellow flowers have been described and since this confusion may arise in the future, it was thought advisable to compare the oils from the two species. The tree bearing the white flowers, *Michelia longifolia* Bl., is a larger tree than *Michelia champaca* L., and the leaves of the former are considerably larger.

The champaca oil described by Schimmel and Company¹⁰ was said to have been prepared from both the yellow and the white flowers. In this oil linalool, methyl eugenol, and methylethyl acetic acid were identified. The yield by distillation is stated to be 0.0125 per cent.

The white flowers do not contain the crystalline ketone obtained from the yellow flowers.

The purified oil was dark green in color and was not fluorescent either when pure or in alcoholic solution. The fluorescence of the sample described by Schimmel and Company was probably due to oil from the yellow variety. It possessed an intensely sweet, almost nauseating odor. The odor of this oil is altogether unlike that from the yellow flowers and may be detected when present in very small amount in the oil from the yellow blossoms. In my opinion its presence in the latter oil seriously impairs the quality of its fragrance.

The constants of the oil are as follows: Specific gravity, 0.897; ester number, 180.0; refractive index, $N_{D}^{30^{\circ}}$, 1.4470.

Owing to the small amount of the sample, about 25 grams, no experiments with the object of removing the color were made. The above constants point to a rather large per cent of the esters of fatty acids.

In a sample weighing 20 grams, linalool, methyl eugenol, methylethyl acetic acid, and acetic acid were identified. A very small per cent of thymol probably also is present. The odor of the oil is chiefly that of the methyl or ethyl ester of methylethyl acetic acid.

Twenty grams of the oil were saponified by slight excess of caustic potash in alcohol. About 1.0 gram of amorphous material separated on cooling, and this material proved to be a wax-like substance. It was deposited in an amorphous form from ether, or ether-ligroin mixture, and in large, gelatinous flocks from hot alcohol.

The alkaline, alcohol solution was concentrated by distilling the alcohol *in vacuo*. Water was then added and the oil separated into neutral, phenol, and acid fractions.

¹⁰*Semi-Annual Rep.*, October (1907), 33.

The neutral portion, weighing 9.3 grams, was distilled at 16 millimeters pressure. The following fractions were obtained:

Fraction.	Boiling point.	Weight.
	°C.	Grams.
I	80 to 90	3.8
II	90 to 98	2.0
III	98 to 110	1.5
IV	110 to 135	1.0
Residue		1.0

Fractions I and II were united and treated with phthalic anhydride in benzene, but no primary alcohols were obtained. The odor of the oil was very suggestive of linalool. Oxidation with chromic acid mixture gave citral, which was identified by its B-naphthocinchoninic acid compound melting at from 196° to 197°.

Fraction III appeared to consist of a mixture of the second and fourth fractions.

Fraction IV, weight about 1.0 gram, had a specific gravity, $\frac{30^{\circ}}{30^{\circ}}$, of about 1.09, and the refractive index, $\frac{30^{\circ}}{D}$, 1.5130. Its odor somewhat resembled that of methyl eugenol. Therefore it was oxidized with potassium permanganate in the cold, and about 0.15 gram of veratric acid, melting point 179° to 180°, was obtained.

No phenolic substances were identified with certainty. After passing carbon dioxide into the alkaline solution and extracting with ether, 5.5 grams of oil were obtained. An attempt was made to distil this portion at 13 millimeters pressure, but only a few drops distilled below 200°. This distillate had a strong odor closely resembling that of thymol. Although it behaved toward alkalis as a phenol it gave no color with ferric chloride, resembling thymol in this respect. It did not crystallize, probably owing to the presence of other substances.

The residue in the distilling flask appeared to have polymerized to a resin.

After the neutral and phenolic substances had been removed, the solution was acidified with sulphuric acid and extracted with ether. After evaporation of the ether the acids were neutralized with soda and a dilute solution of calcium acetate was added. This removed most of the chlorophyll and a small amount of one of the higher fatty acids.¹¹ The methylethyl acetic acid in the filtrate was precipitated as the silver salt, weight 1.2 grams. 1.2000 gram of substance gave 0.624 gram Ag.

Calculated for $C_8H_{10}O_2Ag$, per cent.	Found, per cent.
Ag= 51.4	52.0

¹¹ The substances other than methylethyl acetic acid in the acid fraction weighed about 0.5 gram. These appeared to consist of chlorophyll and a very small amount of a liquid, odorless, fatty acid.

Acetic acid was identified in the final aqueous solution, from which the methylethyl acetic acid had been extracted by acidifying with sulphuric acid and distilling until about one-half of the solution had passed over. The distillate contained 0.156 gram acetic acid. Formic acid was not found.

TODDALIA ASIATICA (L.) KURZ (T. ACULEATA PERS.).

D. Hooper¹² describes the oil distilled from the leaves of this species as having a pleasant odor resembling verbenal or *Basilicum*. According to Gildemeister and Hoffmann,¹³ the oil has a value as a low-priced perfume oil. My results with the oil distilled from the leaves show that it can not profitably be distilled here. A camphor-like compound melting at 96.5° to 97° was obtained from the oil.

The leaves yielded 0.08 per cent of oil by steam distillation. On freezing, the oil deposited 18 per cent of a white crystalline, very volatile compound, having an odor closely resembling that of camphor. After recrystallizing the substance twice from petroleum ether, the melting point was 96.5° to 97°. The compound is very unstable. A pure specimen of it changed in 24 hours to a pasty mixture of oil and unchanged crystals. It was not further investigated. The oil had an odor suggesting a mixture of camphor and lemon grass. Its constants were as follows: $N_{\frac{30}{D}}^{30}$, 1.4620; specific gravity, $\frac{30}{30}$ 0.9059.

The oil is largely linalool, since the fraction boiling from 195° to 200° yields citral on oxidation with chromic acid mixture.

THE ESSENTIAL OIL OF CLAUSENA ANISUM-OLENS (BLANCO) MERR.¹⁴

A quantity of leaves, weighing approximately 16 kilos, were distilled with steam over a period of about five hours and 185 grams of colorless oil were obtained. This oil resembled the fresh leaves in odor and possessed the following constants. Specific gravity, $\frac{30}{30} = 0.963$; $N_{\frac{30}{D}}^{30} = 1.5235$; saponification number 3.6; the oil is inactive.

Fractional distillation at atmospheric pressure of 90 grams of the oil gave the following results:

Temperature.	Fraction.	Per cent.
°C.	Grams.	
212-214	82.0	91.1
214-216	4.5	5.0
216-222	2.5	2.7
Residue.	1.0	1.1

¹² Schimmel and Company, *Semi-Annual Rep.*, (1893), 64.

¹³ Die Aetherischen Oele, Berlin, (1899), 601.

¹⁴ The Tagalog name of *Clausena anisum-olens* is *cayomanes* or *calomata*.

The oil has a faint odor of anise or anethol, which, together with the constants, identifies it almost with certainty as methyl chavicol. For further proof a small portion was oxidized with potassium permanganate to homoanisic acid, melting point, 84° to 86°.

Since the constants given by Bacon¹⁵ for the oil from *Ocimum sanctum* L. differ considerably from those of *Clausena*, and since the oil from *Ocimum* was stated to consist largely of methyl chavicol, 83 grams of the latter oil were fractioned. The results are as follows:

Temperature.	Fraction.	Per cent.
°C.	Grams.	
160-205	15.0	18.0
205-215	43.3	52.3
215-225	16.0	19.3
225-235	3.0	3.6
235-250	2.7	3.2
Residue.	3.0	3.6

Therefore, it is evident that the oil from *Clausena* contains methyl chavicol to the extent of 90 to 95 per cent whereas that from *Ocimum sanctum* contains only 50 to 60 per cent of this substance. Cineol and linalool are also present in the ocimum oil.

The first fraction of the oil from *Ocimum sanctum* was redistilled and 4 grams of oil boiling from 160° to 180° were obtained. The odor of this fraction was very suggestive of cineol, the presence of which was shown by isolating its characteristic hydrobromide. This substance contributes largely to the odor of the original oil. A portion of this low-boiling fraction was sulphonated to test for cymol, but with negative results.

Linalool is present in the fraction, weighing about 5.0 grams, which boiled from 195° to 205°. The phthalic anhydride method for separating primary alcohols, showed alcohols of this character to be absent, at least in amounts exceeding traces.

The occurrence of methyl chavicol, especially in such large proportions, in one of the *Rutaceae* is quite novel.

Bacon¹⁶ stated that alcoholic extracts of the leaves might be used in the preparation of *anisado*, large quantities of which are consumed annually in the Philippine Islands. As a matter of fact, several aromatic plants are used by the Filipinos for preparing liquors on a very small scale. Both *Clausena* and ordinary rosemary, *Rosmarinus officinalis*, which has been introduced here, are used for this purpose. Certain brands of Philippine cigarettes are said to be flavored by the addition of small amounts of *Clausena* leaves.

Owing to the ease with which methyl chavicol is converted into ane-

¹⁵ *This Journal*, Sec. A (1910), 5, 261.

¹⁶ *Loc. cit.*

thol, by treatment with alkalis, it is possible that this operation would be successful commercially. Considerable quantities of anise oil are annually imported into the Philippine Islands for the manufacture of *anisado*. However it is doubtful whether or not *Clausena* could successfully be cultivated, as it is a typical forest species.

LIMNOPHILA SPECIES.

It is worthy of note that the leaves of *Limnophila* sp. of the *Scrophulariaceae*, contain an essential oil the odor of which resembles that of rosemary, of the *Labiatae*. Not enough of the plant has been available this season to study the oil. The yield is approximately 0.2 per cent. Its specific gravity is 0.850, indicating a high per cent of terpenes.

PHILIPPINE CITRUS OILS.

Several varieties of citrus fruits are widely grown in the Philippines, yet no attempt has been made to secure essential oils from them on a commercial scale. The present production of fruit is immediately consumed in the local markets. However, any considerable increase in the number of trees planted would at once bring the manufacture of citrus oils within the range of possibility. The variety of orange now most widely cultivated, the *naranjita*, contains very little acid and, in my opinion, could not be used for making citric acid. In Italy, where practically the world's supply of orange oil is produced, the citric acid which is manufactured from the juice, has a value about equal to the oil obtained from the peel.

It is worthy of note that the Philippine Tariff law, enacted in 1909, places an import duty of 50 per cent *ad valorem* on orange-peel oil. In the United States Tariff Act of 1909, orange-peel oil is not specifically mentioned in the paragraph with neroli, or orange-flower oil, which is on the free list, and the fruit oil therefore would evidently fall under paragraph 21, which provides that "fruit ethers, oils or essences" shall pay an import duty of one dollar per pound. It has been said that this schedule was enacted to protect the California orange growers, but, up to the present, orange oil has not been produced in California in commercial quantities. It would seem that the free entry of Philippine orange-peel oil into the United States would give local producers a decided advantage.

Dr. C. B. Robinson, of the botanical laboratory of the Bureau of Science, supplies the following information:

The orange-growing industry of the Philippines is largely confined to the two towns of Santo Tomas and Tanauan, in the northern part of the Province of Batangas. In many other towns, occasional trees, especially *Citrus decumana* Murr., are planted and grow well, but except in the two places named, the industry is not of commercial importance.

Santo Tomas and Tanauan adjoin one another, the main parts of the towns being about 3 kilometers apart. So far as this industry is concerned, they are now nearly equal, Tanauan having much the larger number of old trees, Santo

Tomas of younger ones. Tanauan also is the larger in population, but Santo Tomas is increasing more rapidly.

Five kinds of oranges are recognized in the local trade, not at all of equal importance. Much the most numerous is that known as *naranjita*, or less often *sintones*, of which Santo Tomas is estimated to have about 125,000 trees. It is *Citrus reticulata* Blanco, which has been considered a synonym of *Citrus aurantium* Linn., the common orange, but the fruit is too loose-skinned for this reduction to be correct. The tree begins to flower in January or February, but the real season is in May and June, fruiting continuing from September to February, but being most copious in the earlier half of this period. The trees are prolific, bearing up to 6,000 oranges, or more than they are able to sustain. The fruit is shipped in large baskets, holding 600 to 700 oranges each, and has a ready sale not only in Manila, but in all of the provinces easy of access.

Next in number is the *cajel*, a larger orange with a tighter skin, having approximately the same flowering and fruiting season as the *naranjita*. It is *Citrus aurantium* Blanco, and perhaps the Linnaean species of that name, but is not quite the same as any of the American varieties of that species. It has a similar, but less extended sale than the *naranjita*.

In Batangas, *Citrus decumana* Murr., usually known there as *naranja*, is third in importance. In other districts of the Philippines, its relative position is higher, and the more common names are *lucban* and *suja*. It is cultivated in many places, but is held in less esteem than *naranjita*, although it is often to be found on sale in Manila and elsewhere. Almost exactly similar fruit is imported from China. The fruits are much the largest of those of any of our species of *Citrus*.

The two remaining cultivated oranges are the *calamansi* and the *tison*. The former is more acid than any of the others, and is little used except as a substitute for lemons. The latter, from description, more nearly resembles some of the American varieties of orange than do any others grown in the Philippines. It probably is *Citrus papillaris* Blanco.

In addition, the wild-orange, *Citrus hystrix* DC., called *cabuyao*, is found in Batangas. It has no commercial value, but might be suitable for grafting.

There are also two kinds of lemons, known locally as *limon* and *limoncito*.

Therefore, practically the trade may be considered to be confined to two kinds of oranges, *naranjita* and *cajel*, in the order named. The former is not only the more numerous, but its cultivation is very rapidly increasing. It is of slower growth than the *cajel*, the latter requiring about 3 years from planting to fruiting, the former about 5.

It will shortly be possible to give accurate statements of the botanical position of all these species.

Fine, large lemons, grown from the seed of Italian lemons, are raised in one or two localities in the mountains of northern Luzon but, so far, no attempt at extensive cultivation has been made. Therefore, true lemon oil can not be produced in the Philippines at the present time, or in the immediate future.

Orange-peel oil can be prepared from the two varieties, *naranjita* and *cajel*. The peel of the former contains much more oil than the latter, and also probably more than the average California orange. The yield is greater when the peels are green than when they are fully ripe.

The green oranges weigh, on an average, about 160 grams, of which about 40 grams are peel. On an average the peel of a green orange yields, on squeezing by hand, about 0.5 gram of oil and 2 cubic centimeters of an aqueous solution which contains a considerable amount of reducing sugars. No evidence of the presence of a glucoside was found. The freshly pressed oil has the following constants Ester number, 8.0; optical rotation, $A_{\frac{30^\circ}{D}}$, 90.85°; refractive index, $N_{\frac{30^\circ}{D}}$, 1.4700.

On standing a few days, the freshly pressed oil deposits about 0.3 per cent of a crystalline, wax-like substance, perhaps identical with the orange-oil stearoptene which separates from Italian sweet-orange oil. By squeezing the peels into alcohol and precipitating with water an oil is obtained which does not deposit any sediment on standing. One such sample gave, on spontaneous evaporation, a residue of 2.25 per cent of the solid. Another specimen of oil, obtained by pressing only, left a residue of 2.4 per cent. After recrystallizing the solid several times from dilute alcohol, it showed the melting point 116° to 117°.

The constants given above agree well with those of the orange-peel oil of commerce. Schimmel and Company¹⁷ assign the following limits to the constants of oil of sweet-orange peel: $d_{15}^\circ = 0.843$ to 0.853 ; $(D)_{\frac{20^\circ}{D}} = 95^\circ$ to 98° . The residue on evaporation should be between 2.0 and 4.0 per cent.

In order further to confirm the character of this oil it was investigated and found to contain about 92 per cent of limonene. Wallach¹⁸ found about 90 per cent of limonene in a European sweet-orange-peel oil.

As orange-peel oil has been investigated very thoroughly, it was not deemed necessary to repeat previous researches in this instance. The oil in question appears to be identical with the orange-peel oil of commerce.

One hundred and five grams of oil gave 96 grams of limonene, $A_{\frac{30^\circ}{D}} = 93.20^\circ$ and 4.5 grams of oil boiling from 180° to 230°. This fraction was redistilled but the quantities of substances obtained were too small for identification. About 0.5 gram of an acid was secured, the odor of which was slightly suggestive of butyric acid, but the odor of the ester closely resembled that of caprylic ester. The acid fraction also contained a trace of a phenolic substance which gave an intense, wine-red to violet coloration with ferric chloride.

The odor of the Philippine oil is just as fine as the oil produced elsewhere, being decidedly sweeter than several samples of Sicilian oil procured in Manila. However, the latter samples undoubtedly had deteriorated during storage.

The oil from the *cajel* variety of orange is very difficult to press out of the peel, as the oil cells are set very deeply. It does not differ perceptibly in fragrance from the oil of the *naranjita* and the yield is so small that no attempt was made to prepare a quantity of it. A small sample showed the refractive index, 1.4675; the specific gravity $\frac{30^\circ}{30^\circ}$, 0.8390; and the saponification number, 8.5.

¹⁷ Bulletin of Schimmel and Co. (1906), 3, 35.

¹⁸ *Ann. d. Chem.*, (Liebig) (1884), 227, 289.

THE ESSENTIAL OIL OF CITRUS DECUMANA MURR.

The oil in the peel of the fruit of this species, which is commonly known to Americans as grapefruit or pomelo, is very difficult to express and appears to have no extraordinary merit. The oil from the leaves has never been described. The leaves are extremely fragrant and on distillation with steam yield about 1.7 per cent of an oil having a very fine odor. The constants of a sample prepared in this way were as follows: Specific gravity, $\frac{30^\circ}{30^\circ}$, 0.8700; ester number 10; optical rotation, $A \frac{30^\circ}{D}$ 22.90° refractive index, $N \frac{30^\circ}{D}$, 1.4644. It is miscible with 70 per cent alcohol.

It appears probable that there are two varieties of pomelo trees. It has been noted that one variety has large leaves with almost no oil; the other has a much smaller leaf and the branches are quite thorny. The small leaves are full of oil cells and give the yield on distillation noted above.

The oil contains less than 1 per cent of aldehydes. Treatment of 40 grams of oil with sodium acid sulphite, in the cold, and subsequent treatment of the sulphite solution, gave one or two drops only of an oil having an odor like citral. Thirty-nine grams of the oil were recovered.

Dipentene constitutes about 25 per cent of the oil, as was shown by isolating a fraction boiling from 174°–176°, $A \frac{30^\circ}{D} = +2.35^\circ$; $N \frac{30^\circ}{D} = 1.4750$ and specific gravity $\frac{30^\circ}{30^\circ} = 0.8181$ which gave dipentene tetrabromide, melting point 120°. The fraction boiling from 195° to 200°, 15 per cent of the oil, contains linalool, as was shown by oxidizing to citral by chromic acid mixture.

CITRUS HYSTRIX, DC.

The oil of *Citrus hystrix* DC. is referred to by Schimmel and Company¹⁹ as having an odor somewhat resembling that of bergamot. The oil distilled here from the leaves possesses an odor very much resembling that distilled from the leaves of the pomelo, *Citrus decumana* Murr. It is very fragrant but the yield is so poor, not more than 0.08 per cent, that a quantity sufficient for investigation was not distilled. The constants of the oil are as follows: Specific gravity, $\frac{30^\circ}{30^\circ} = 0.9150$; $N \frac{30^\circ}{D} = 1.4650$; $A \frac{30^\circ}{D} = -10.50^\circ$; saponification number, 50.2.

OIL OF YLANG-YLANG.

Since the oils prepared by Bacon²⁰ by extraction were of such excellent quality and possessed high ester numbers, and since benzyl alcohol has been found by Soden and Rojan²¹ in the distillation water of ylang-ylang flowers, it was thought that perhaps some of the esters present in the

¹⁹ *Semiannual Report* (1901), 2.

²⁰ *This Journal*, Sec. A (1909, 4, 129.

²¹ *Ber d. Deutschen Chem. Ges.* (1901), 34, 2809.

original oil suffered considerable saponification during steam distillation at ordinary pressure. Accordingly, a sample of ylang-ylang oil which had been prepared by extraction with petroleum ether, was boiled with water, under a return condenser, for five hours. Although the distillation of ylang-ylang flowers ordinarily lasts 5 hours or more, the conditions of this experiment are more severe than those obtaining in practice, except perhaps when the distillation water is continually returned to the still.

Five grams of oil and 15 cubic centimeters of water were used in the experiment. The flask containing the mixture was heated by an oil bath kept at 105° to 110°. At the end of 5 hours the aqueous solution was titrated with $\frac{N}{10}$ caustic soda solution and the saponification number of the oil was also determined. A decrease in the saponification number of only 4 units was observed. A sample of first quality distilled oil, having an ester number of 112, showed a decrease of 2 units when treated in the same way. For the purpose of comparison, 8.0 grams of benzyl acetate were treated in the same manner. After 5 hours' boiling, the aqueous solution required 32 cubic centimeters of $\frac{N}{10}$ caustic soda for neutralization, corresponding to a decrease in the ester number of the oil of about 22 units.

Therefore, it is most probable that the high ester number of first quality, distilled, ylang-ylang oils and the low numbers of second quality oils are due to the fact that considerable fractional separation is effected by steam distillation and that no considerable percentage of the esters originally present are saponified. As suggested by Bacon,²² the difference in quality between the extracted and distilled oils probably is due to the alteration of constituents which are present only in very small amount and also to the acquisition of deleterious odors which owe their origin to decomposition in the flower tissues themselves during the distillation.

During the past season, 15 samples of ylang-ylang oil have been examined in the chemical laboratory, of the Bureau of Science. The maximum ester number found was 151, and the minimum 83.2. Two of the samples were graded as second class.

ACACIA FARNESIANA (L.) WILLD.

It is interesting to note that *Acacia farnesiana* (L.) Willd., which bears the well known *cassie* flower, has been introduced into the Philippines and now grows wild over a large part of the Archipelago. In certain places this shrub, or tree, grows in dense thickets, and when in flower the air in the vicinity is very fragrant. It is possible that it would pay to cultivate this flower here. The perfume factories of southern France pay 3.5 to 5 francs per kilo for the flowers, which is equal to about 1.40 to 2 pesos, Philippine currency. Unskilled Philippine laborers are paid from 80 centavos to 1.00 peso per day, while boys may be hired for light tasks for very much less.

²² *Loc. cit.*

GENERAL.

An oil of exceptionally fine fragrance and which may prove to be a new oil from some species of *Andropogon*, has been examined recently in the chemical laboratory of the Bureau of Science. Unfortunately, botanical material at present is not available.

The constants of this oil were as follows: Sp. Gr. $\frac{30^\circ}{30^\circ}$, 0.8777; $A \frac{30^\circ}{D}$ inactive $N \frac{30^\circ}{D}$ 1.4868; aldehydes, largely citral 72 per cent; geraniol 12 per cent. The oil is optically inactive.

The geraniol was estimated by the customary calcium chloride method, and the semicarbazone of the aldehyde, after three recrystallizations from dilute alcohol, melted at 155° to 160°.

The perfumes sold in the local market under the name of champaca do not duplicate the odor of the flower at all. This is also true of the frangipani which commonly is supposed to be derived from the cemetery flower or *Plumeria acutifolia* Poir.

SUMMARY.

(1) An oxidizing ferment is present in the flowers of *Michelia champaca* L. and *Michelia longifolia* Bl.

(2) The constants of the oils from white and yellow champaca flowers have been determined and their properties described. The differences between the two oils are clearly drawn.

(3) The oil from white champaca blossoms contains linalool, methyl eugenol, methyl-ethyl acetic acid, probably in the form of the methyl or ethyl ester, acetic acid probably as linalyl acetate, and a phenolic substance possessing an odor closely resembling thymol.

(4) In addition to isoreugenol, the essential oil of yellow champaca flowers contains benzoic acid, benzyl alcohol, benzaldehyde, cineol, and *p*-cresol methyl ether.

(5) The essential oil of *Clausena anisum-olens* (Blanco) Merr. has been prepared. The yield is about 1.20 per cent. It contains methyl chavicol to the extent of about 93 per cent.

(6) Orange-peel oil from the common Philippine varieties of orange has been made and its properties determined.

(7) The oils distilled from the leaves of *Citrus decumana*, *Citrus hystrix*, and *Toddalia aculeata* are described.

ILLUSTRATIONS.

(Photographs by Cortez.)

PLATE I. *Michelia champaca* L.

II. *Canangium odoratum* Baill.



PLATE I.



PLATE II.

EDITORIALS.

THE FLUCTUATION IN THE VALUE OF YLANG-YLANG OIL AND SOME OF ITS CAUSES.

Various causes have been assigned to the decline in value which ylang-ylang oil has suffered in the last few years. It is stated sometimes that chemical studies on products of this class enable better synthetic products to be manufactured. This is often quite the truth. However, there are many instances where substances are elaborated by nature and may be manufactured directly from the plants containing the desired product cheaper than by any known laboratory method of synthesis. This always will be true of rubber, many of the sugars, and most of the alkaloids and the essential oils. In the case of the essential oils entering into the manufacture of the better grade of perfumes, the relative valuation depends, to a degree comparable probably only with works of art, upon the quality of the finished product. Some of the largest manufacturers of the essential oils who are working directly from flowers, state that the introduction of synthetic preparations has not made serious inroads upon their business. The majority of the synthetic preparations are not better than second quality natural products. This undoubtedly is true of ylang-ylang oil.¹ In the discussion of the fluctuations in the price of ylang-ylang oil this point should be kept in mind.

Briefly, the chief cause for the present decline in prices appears to be overproduction. The political disturbances of a decade ago and the precarious state of trade in some districts greatly curtailed the production of ylang-ylang oil. For some time there was the keenest competition among distillers in the purchase of flowers. The increase in the demand for and cost of labor and the general increase in cost of living subsequent to the American occupation perhaps contributed to increase the

¹The work done in the chemical laboratory of the Bureau of Science by Dr. R. F. Bacon on ylang-ylang oil has been of distinct value to local distillers and dealers in this oil, in enabling buyers of oil produced in the provinces and exporters to corroborate their opinion as to whether or not a given sample of oil is first or second quality, by means of exact analytical data. A few cases of dispute between buyers and sellers of ylang-ylang oil have been tried in the courts of Manila, and the results of the researches of the laboratory have been of assistance in such instances.

difficulties of the distiller. At any rate, a rise in prices was anticipated by European firms, and their anticipations were realized.

At the same time that prices rose, and probably because they did, ylang-ylang trees began to be extensively cultivated elsewhere, particularly in Java and in the French colony of Reunion. Ylang-ylang oils have since been reported also from Jamaica, Bangkok, Tonkin, Nossi-Bé, Mayotte, and the Comoros. However, the continued maintenance of the high prices for Philippine oil of ylang-ylang would have been entirely an artificial condition, except in 1905 when the trees were badly damaged by a destructive typhoon, and one which, in view of the stimulus to ylang-ylang growing elsewhere, could have been hardly expected to continue. However, this brings out an interesting fact. The oils produced in other localities are all of inferior quality compared with the best Manila oil, and have not and do not now command such high prices as the best Philippine oils. In fact, the Java oil is known to the trade as cananga oil, although produced by the same species.

The care and skill with which the oil is distilled in the different localities named undoubtedly has something to do with this, but it is highly probable that, as has been suggested by the chemists of Roure-Bertrand Fils, climatic differences are of great importance. Be the causes what they may, the quality of first class Philippine ylang-ylang oil has not been equaled elsewhere, and after a thorough trial of Reunion oils, certain French firms have turned again to Philippine distillers for first quality oils. The production of large quantities of oil in Reunion and Java has flooded the market with oils of the second class. This class of oil probably also suffers to a small extent from the manufacture of the synthetic product. In considering the result of the production of such large quantities of ylang-ylang oil, it must be remembered that the market for such a commodity is quite limited, so that the effect on the prevailing prices is quickly felt.

The following abstracts from the semi-annual reports of the firms of Schimmel and Company and Roure-Bertrand Fils may be of interest.

A rise in prices should cause no surprise in view of the difficult circumstances. Report Schimmel & Co. (1899), 2, 56. The shipments only sufficed for the most pressing demands. Report Schimmel & Co. (1900), 1, 48.

Generally speaking, there is on the various European markets a decided scarcity of fine ylang-ylang oil, with an abundance of medium and cheaper qualities. The last named have, in reality, no higher value than cananga oil. Report Schimmel & Co. (1901), 1, 53.

But one thing appears to be without doubt, namely, that in Java the care devoted to the distillation is not sufficient to make it possible to obtain oils of ylang of superior quality. Bull. Roure-Bertrand Fils (1902), 1, 38.

There is such a competition in the purchase of the flowers that the prices are driven up beyond all limits. Report Schimmel & Co. (1903), 1, 78.

Speaking of the plantations started near Tonkin, Roure-Bertrand Fils state that these are certainly to be encouraged.

For the oil of ylang has become of prime necessity in perfumery and it is troublesome to depend on the production of a single country, the stability of which is far from being assured. Bull. Roure-Bertrand Fils (1902), 2, 30.

It would seem that the very high rates which we have experienced for several years ought to be modified to a very sensible extent. Such however, has not been the case. This is due to causes absolutely independent of the abundance of the harvests. Bull. Roure-Bertrand Fils (1904), 1, 48.

We have received a large shipment of several thousand bottles [of cananga oil] direct from Batavia. Report Schimmel & Co. (1904), 2, 16.

Exceptionally fine qualities can always be sold quickly and without trouble, but medium qualities remain difficult to dispose of and are frequently replaced by fine cananga oil. Report Schimmel & Co. (1904), 2, 92.

There is an imminent danger of over-production [of Réunion oil] and a consequent slump in the prices. Report Schimmel & Co. (1906), 2.

The following paragraph illustrates the advantage of employing analytical data in the valuation of the oil.

Good qualities are always sought after and fetch high prices. This is explained by the fact that, outside the well known brands, it is difficult to buy this oil with proper security. Bull. Roure-Bertrand Fils (1907), 1, 37.

Roure-Bertrand make the following statement in regard to Réunion oil:

This oil is of very good quality, but it differs distinctly in odor from that of Manila oil, so that the one can not be employed as the equivalent of the other. Bull. Roure-Bertrand Fils (1909), 1, 57.

In the same year Schimmel and Company call attention to the increased production in Réunion, and state also that about 25,000 trees were set out in the Island of Nossi-Bé near Madagascar. They also comment on the results obtained on ylang-ylang oil by De Jong in Java. As the chemists of the above firm point out, better methods of distillation undoubtedly would improve the quality of Java oil, yet it is worthy of note that De Jong did not obtain oils having ester numbers higher than 37.3 and saponification number after acetylation greater than 66.7 to 77.8, showing a much lower content of both alcohols and their esters than good Philippine oil.

In April, 1910, Roure-Bertrand Fils state that the market was flooded with second quality oils. "The competition of oils from the French colonies is becoming daily more formidable." The best Philippine oil is quoted at less than 400 francs. They estimate that the production of ylang-ylang oil in Réunion, during the year 1910, exceeds 2,000 kilos, and state that in two or three years this will amount to 4,000 kilos.

In their semiannual report for April, 1910, Schimmel and Company comment on the enormous production of ylang-ylang oil in Réunion and

recall the fact that "the average price of 500 francs per kilo has thereby been reduced to about 300 francs."

It would be highly desirable to give accurate statistics showing the export of ylang-ylang oil from the Philippine Islands and from Réunion and of cananga oil from Java. Such statistics as do exist, at least for the Philippine Islands, are altogether unreliable. Thus, if we would believe the figures given in the report on the Foreign Commerce of the Philippine Islands issued by the Bureau of Insular Affairs at Washington, we would learn that in 1907 9,012 gallons of ylang-ylang oil were produced, valued at 18.78 dollars per gallon, whereas in 1908 there were produced 1,088 gallons valued at 109.40 dollars per gallon.

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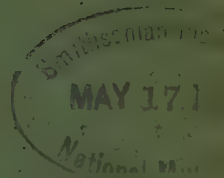
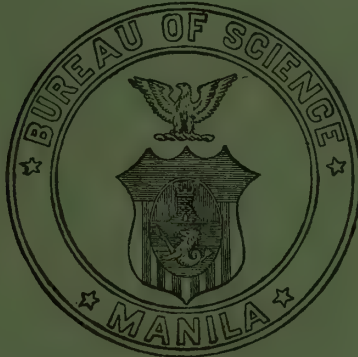
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No. 5

GEOLOGICAL RECONNAISSANCE OF MINDANAO AND SULU: III. GENERAL AND ECONOMIC GEOLOGY.

By WARREN D. SMITH.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

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I. GENERAL CONSIDERATIONS.

I discussed in Chapter II¹ the physiography of Mindanao by units, lakes, plains, etc. In this number I shall treat of the geology by districts which more or less closely conform to the political divisions, reviewing briefly in each case the various physiographic features.

Geologically, Mindanao is to be considered a part of the great chain of outliers of the ancient Australasian continent, a part of the crumpled continental shelf. As it is situated at the very edge of that shelf, the formations which appear at the surface to-day would of course be of

¹ *This Journal, Sec. A (1910), 5, 345.*

the youngest. The principal tectonic lines run generally north and south, thus conforming approximately to the Asiatic coast line. One of the deepest parts of the Pacific lies directly off the east coast of this island,² and hence Mindanao marks the eastern edge of the continental horst.

So far as we now know, there are no rocks in Mindanao and Sulu which we can with certainty say are older than the Tertiary. There are two good reasons for this: First, this territory apparently has emerged from the sea so recently that the streams have not been able to cut through the overlying formations to the older ones below; and second, but little has been done in the way of excavation and boring. Mindanao differs in this respect but slightly from the rest of the Archipelago.

As it is almost impossible anywhere to see other than very limited geologic sections, we must leave much to conjecture in regard to the succession of formations in Mindanao. Still less can be observed in Sulu, where practically everything is blanketed by recent volcanics. However, by piecing the isolated facts together we can arrive at the following provisional scheme:

Provisional stratigraphic scheme.

Recent:	Miocene:
Coral reefs.	Limestones and shales.
Piedmont deposits.	Coal (?)
River alluvium, etc.	Oligocene and Eocene:
Raised beaches.	Coal measures.
Andesites.	Unconformity (?)
Basalts, etc.	Uncertain but probably Tertiary:
Pliocene:	Schists.
Limestones.	Unconformity.
Volcanics.	Deep-seated igneous with conglom-
Unconformity.	merates and various intrusive
	rocks.

II. DISTRICTS.

ZAMBOANGA.

Physiography.—In the Zamboanga district I shall include the large Island of Basilan which is off the southern end of the peninsula, and the long narrow peninsula itself up to a line extending from Sindangan Bay south to Sibuguey Bay. This territory is characterized by its rugged topography, indented coast line, lack of any considerable coastal plain, numerous reefs, short, shallow and swift rivers, heavy forests, and few settlements of any importance.

The only large settlement is Zamboanga, situated at the edge of the broad plain at the southern extremity of the peninsula. As I have

² *Ann. d. Hydrog. u. mar. Met.* (1906), 556.

already said, Zamboanga is a "gate city," its importance being due to its location at the intersection of several trade routes. It owes very little to the country immediately back of it. We shall see the importance of this when we compare it with such localities as those of Cotabato and Butuan. Zamboanga does not even lie near a river. The Tumaga, hardly deserving of the name of river, which rises in the mountains, formerly emptied into the sea somewhere near Zamboanga, but now it turns sharply to the east near the *barrio* of Santa Maria and has its mouth at Port Masinloc. The greater part of the coastal plains of Zamboanga and Basilan are largely inhabited by Moros, a constantly shifting population, living most of the time in boats and coming ashore only to trade. The rugged interior of Basilan is peopled by Yakans, who are called "Hill Moros," and the Zamboanga Peninsula by Subanuns. The Subanuns are a very primitive people who have retreated before the advance of the Moros and who now live in a nomadic state, constantly changing their abodes from one clearing to another. These clearings are known as *kainġins*.

Stratigraphy.—Good geologic sections are, as elsewhere, very difficult to find in the Zamboanga Peninsula. However, some very satisfactory exposures of limited extent may be seen in the gorge of the Tumaga River and at several points along this stream to the north. By piecing together the information gathered from scattered outcrops, we can approximate the stratigraphic succession. The basal rock, as in the northern islands, is probably a diorite, although I have seen this only in pebbles in the streams. Presumably above this diorite lies a basal conglomerate. The next formation in the peninsula proper is a schist, which may simply be metamorphosed sandstones and shales. This schist is found best exposed in the beds of the streams which run along the long axis of the peninsula. It is completely buried in other localities by later volcanic flows and alluvium, but can be seen well for about twenty-four kilometers along the bed of the Tumaga River. This schist dips to the east at an angle of about 45° and with a strike of nearly 40° east. It is a grayish to green rock, with a considerable development of chlorite along the plains of schistosity, and is characterized by numerous small stringers of auriferous quartz. In a thin section it is seen to consist of long, frayed-out, green hornblendes with granular quartz and feldspar, with the quartz dominant, these two minerals lying between the fragments of hornblende. The schistosity is very marked in the microscopic slide. The large amount of quartz seems to confirm the supposition that it is a metamorphosed sandstone. Other samples show an abundance of chlorite and some small sections of apatite. I found an outcrop of fossiliferous shale near the gorge of the Tumaga River, the relation of which to the schist I was unable to determine. However, I think it must be much younger. This shale is identical with that overlying the coal seams

in Cebu, and contains the well known fossil *Vicarya callosa* Jenks., which occurs just above the coal in the Visayas and Luzon.

Next above the schist comes andesite, which is the dominant rock in the Zamboanga Peninsula. A large amount probably was derived from an old vent now represented by Mount Panubigan, a peak of some 1,220 meters elevation, about eighty kilometers north of Zamboanga. This andesite so completely covers the underlying rocks that the occurrence of schists and other formations in the Zamboanga Peninsula never before has been noted by geologists.

While traversing a small stream back of San Ramon farm on the west coast of the peninsula, I found pieces of schist included in the andesite, which demonstrated that the latter was of later origin than the former, and while in a molten state had caught up loose fragments of the underlying formation and subsequently had cooled around them. The German traveler and geographer, Baron von Richtofen, mentions the finding of nummulitic limestone in a piece of float near Zamboanga. I also found pieces of this float, but while I could see no *Nummulites*, I discovered fragments of *Orbitoides* in it. I found none of this limestone in place. However, back in the central and higher part of the range there may be remnants of this formation.

My observations on the Island of Basilan were limited to the northern part in the vicinity of the town of Isabela. The hostile state of the Moros at the time of my visit prevented much travel in the interior. Wherever I went and as far as I could see from the boat, I found the island largely covered by a mantle of andesite and basalt. It is a densely wooded region with numerous volcanic cones and gentle slopes. The soil is heavy and red. A typical specimen of basalt, exceedingly fine-grained, was taken from the hill just back of Mr. Musser's plantation. The chief minerals are plagioclase (labradorite and anorthite), augite, olivine, and magnetite; in addition, innumerable minute grains of highly refracting substances occur which might easily be confused with any one of the three minerals, zoisite, vesuvianite, and corundum. They are almost colorless, have a bluish, sometimes greenish, cast, a high index of refraction, low double refraction, and no pleochroism. I am of the opinion that they correspond to the substance noted by Büching in the basalts from Breitfiert. The structure of this rock is pronouncedly ophitic. Another rock obtained from Basilan, and which is found in the old collection of the Spanish Mining Bureau, is a gabbro. This consists of a perfect network of rods or lath-shaped plagioclases (oligoclase) with more or less granular pyroxenes (diopside or diallage) in the interstices or partially intergrown with the feldspars. There is also some magnetite. The granular appearance of the pyroxenes is due to the basal cleavage. An analysis of Basilan gabbro is as follows:

Analysis of Basilan gabbro.³

	Per cent.		Per cent.
SiO ₂ -----	52.47	H ₂ O loss on ignition -----	0.80
Al ₂ O ₃ -----	17.16	TiO ₂ -----	1.53
Fe ₂ O ₃ -----	1.89	P ₂ O ₅ -----	Trace.
FeO -----	8.08	Cl -----	Trace.
MgO -----	5.32	S -----	Trace.
CaO -----	9.21	MnO -----	0.36
Na ₂ O -----	0.82	Total -----	99.59
K ₂ O -----	0.36		
H ₂ O below 105° -----	1.59		

Turning attention next to the vicinity of Zamboanga, we find a coastal plain perfectly flat and with a width varying from one to ten kilometers. The substructure is a coral-reef or a series of them. Coral is growing in the sea at the edge of this plain at the present time, and in walking from Zamboanga north to the Zamboanga gorge, at least two older reefs which marked the former edges of the plain, are crossed. A varying thickness of detritus washed from the mountains is superimposed upon this substructure, but no consolidated formations are encountered. A broad platform extends out from the gorge, really a very gently sloping alluvial fan, which is known locally as the *mesa*. There is a depressed area just in front of and parallel to the gorge which marks a former position of the coast line. This is termed a *cuesta*. At the gorge we found a vast cliff of andesite. Near the *barrio* of Masiay we again encountered this volcanic rock outcropping on the banks of the San Roque River; here it does not occur as a cliff, but in low hills. This rock has all the characteristics of a surface flow, but it is a very old one, as the vesicles or "blow holes" have been filled with secondary mineral matter. At the foot of the hill on which is located "Station M" on Captain Moore's map, I found a calcareous formation with true bedding planes dipping at an angle of 29° to the southeast and with a strike north 42° east. This is the only outcrop of a sedimentary I have found near Zamboanga.

A well was sunk to an approximate depth of 165 meters on the military post at Zamboanga, with the hope of finding water, but without result. It is barely possible that a supply of water might have been obtained by going deeper, but it seems to me that on account of the loose material composing the Zamboanga plain and the probable impounding of any water which has come from the lava formation by the old reefs which occur between the gorge and Zamboanga, it is not likely that the project would have been successful within a reasonable expenditure of money. If the sediments, which I noted near the "Station M", persist in their dip, they would never emerge again at the edge of the plain.

³ Analysis by R. R. Williams, Bureau of Science.

Seeing no hope of finding a good water bearing stratum, such as a sandstone, I expressed the opinion then (1907), and I still think, that it would be much more feasible to construct a dam at the gorge of the Tumaga River and obtain a supply of water as is done for Manila.

Economic.—Under this heading I shall discuss two deposits in this district which appear to give some promise of becoming important. One is the gold prospect on the Tumaga River about forty kilometers north of Zamboanga. The metal is encountered in a sticky clay, the upper weathered portion of the schist formation which I have already alluded to as forming the core of the peninsula. The gold comes from quartz stringers which occur in the planes of schistosity. No veins large enough to work as lodes have been located. The only apparently profitable method of working such placer ground would be hydraulic, and as the city of Zamboanga is intending to dam the Tumaga River to obtain a supply of water, there may be some objection to this method. Three or four Zamboanga prospectors sluiced very industriously in this region for over a year in 1905 to 1906. One was killed by the hill people and the others abandoned the work. It is reported that they obtained fair returns. Prospecting for the main lode should be continued, but I should recommend strongly that placer ground near the coast be examined, as dredging in the lower reaches of these rivers would undoubtedly pay more than the work in the central part of the peninsula, where all transportation facilities are lacking, and all expenses would be exceedingly large. When I examined the Tumaga prospect in 1907, I found that a canal about 300 meters in length had been extended from the Tumaga River to conduct water into a large, circular excavation, which in turn was drained by a long sluice 10 to 12 meters in length. I tried panning the stiff clay at this locality but found it exceedingly tedious work, due to the toughness of the material, but was rewarded by a few colors. The occurrence of the gold here seems to be very much the same as it is in the Surigao Peninsula.

Some prospecting is being done near Kuruon, but I have been unable to learn the result. As the prospector is working in the lower reaches of the river, I believe he is more likely to obtain results than the men who are located in the cordillera. Reports of the finding of gold are continually being brought in from all the small streams along this coast.

The second prospect of probable commercial importance is the coal on the Siay River near the head of Sibuguey Bay. I visited this deposit in December, 1907, and again in 1911. It is about nineteen kilometers from the mouth of the river, in low country, with a few, small, heavily forested hills. This deposit was partially developed in the first years of the American occupation, but a miner was killed and work abandoned.

The coal in the outcrop has a very encouraging appearance, being much the same as the coals of Cebu and Polillo Islands. I can not state the condition in places farther under cover, because all the tunnels were

caved in and I found the entrance with difficulty. I think this locality an exceptionally favorable one for further exploration, because the coal outcrops about fourteen meters from the Siay River and has only a moderate inclination. Lighters could be towed up this river by small steam launches within a few yards of the mine mouth. Of course, at the present time the river is full of snags but these could easily be cleared out.

Analysis of Sibuguey coal.

	Per cent.
Moisture	6.55
Volatile combustible matter	41.95
Fixed carbon	48.10
Ash	3.40
Sulphur	0.26

Sibuguey Bay is well protected and is not in the typhoon region so that safe anchorage for ships could be obtained. However, there is one difficulty: Extensive reefs are found all around this coast, making navigation exceedingly difficult, but this condition is largely ameliorated by the fact that the Coast and Geodetic Survey has completed accurate charts of all the waters near the Siay River. I believe that the coal measures, which are not at all metamorphosed on the eastern side of Sibuguey Bay, continue around and into the Zamboanga Peninsula, where they may be metamorphosed with the schists. If the coal should continue, there is great likelihood of a better grade being found in the lower part of the peninsula, where great pressure has been exerted on the rocks. This can only be ascertained by drilling or sinking a shaft, as I know of no place where the streams have cut deep enough on the sides of the anticline to expose the underlying coal measures.

At the foot of the Tres Reyes Peaks, not far from Margus Tubig, on Dumanquilas Bay, Mr. Cleveland has discovered and partially opened up a half-meter seam of coal, which in physical and chemical characteristics is semi-anthracite. Whether or not there is a thicker seam below has not been determined. Below is an analysis of this coal from a sample collected by me. About 100 meters from the first outcrop is a second where the coal is entirely metamorphosed, resembling very closely the columnar structure of basalt, the well known basalt "columns." This is well shown in the photograph on Plate V.

Analysis of Tres Reyes coal.⁴

	Per cent.
Moisture	1.85
Volatile combustible matter	10.43
Fixed carbon	82.34
Ash	5.38

Calorific value, 7,695 calories.

⁴ Analysis by Forest B. Beyer, Bureau of Science.

Should a thicker seam be discovered here, mining would not be difficult, as the other features are all favorable. This deposit is located within 6 or 7 kilometers of tide water.

Before leaving the Zamboanga district, I desire to call attention to the heavy, red soil which is to be found covering a large part of the Island of Basilan, as well as many other portions of Mindanao and Sulu. This material seems to be in spots more in the nature of an iron formation than a soil. In some places it is hard and carries a considerable percentage of iron, in others it is simply a highly ferruginous clay. Laterite appears to me to be the best name for this deposit, as it seems to correspond in many ways to a similar formation or formations so named in India. It is characteristic of the Tropics where weathering extends to a considerable depth and where the surface rocks are rich in iron minerals, as is the case over a large part of western Mindanao and the Sulu Archipelago. The origin of laterite has been a matter of heated discussion, and hundreds of pages have been written defending first one theory and then another. The formation in the Philippines, which I shall call laterite seems to me in general to be a product of weathering.

Soil.—The soils of Basilan Island are excellently adapted to the growing of rubber and hemp and here are located several thriving young plantations. Rubber trees and hemp plants are now growing on Doctor Strong's plantation.

The Zamboanga plain is much better adapted to coconuts, as it has a more or less sandy soil and is more exposed to the sea. The hill country of the peninsula has little cultivated land; *camotes* are practically all that is raised by the natives. The hot and moist swales between the ridges are excellent locations for hemp growing.

THE MALINDANG DISTRICT.

Very little definite information is to be obtained regarding the Malindang district. I have touched it at Dapitan on the north coast, and at Pangil Bay. From the latter point I made short trips up the sides of Mount Malindang. Major Edgar A. Mearns, United States Army, ascended Mount Malindang in 1906 but has left practically no record of the geology encountered. An exploring expedition from Misamis to Dumanquilis Bay was undertaken in 1904 by a detachment of Troop G, 14th Cavalry, under Captain C. C. Smith. A route map was made and the report submitted to the Adjutant General of the Philippines; however, this gives no geologic information. The chief value of the map to those outside of the Army is the fairly accurate location and sketch of Lake Leonard Wood near the *ranchería* Payan.

In December, 1907, I visited the town of Misamis on the west coast of Pangil Bay, and in company with Lieutenant Lattamore, Philippine Constabulary, went to several points around Pangil Bay. I found every-

where a rich, red soil, very much like that of the Hawaiian Islands, splendid agricultural country, and the rocks, wherever exposed, basaltic or andesitic. Mount Malindang is evidently an old volcanic stock and shows signs of extensive erosion. I doubt if it has been in eruption since the Pleistocene. There are several other old stocks in this district. A fine strip of coastal plain extends north from Misamis through Jimenez or Oroquieta to Langaran. This coastal plain varies from 1 to 12 kilometers in width, and is very fertile agricultural land where coconuts flourish. In fact, this part of the district bordering Iligan Bay appears to be one of the finest agricultural districts in the Archipelago.

The country is very rugged west of Malindang, there being several prominent peaks, of which Mount Dapiok and Sugar Loaf are the most conspicuous. The north coast in the vicinity of Dapitan is of the same character and gives every evidence of recent elevation. I did not land at Dapitan, but went close enough to the shore to be able to make out limestone cliffs with my glass. I know of no economic deposits in the district. There should be an abundance of coal and limestone which might be developed. It is fairly safe to predict that gold also will be found in many of the streams. The hill country of this district is inhabited by Subanuns; the coast towns are peopled largely with Visayans from Cebu and Negros, and with Chinese, of course, the chief traders.

THE LANAO DISTRICT.

Physiography.—I have already referred to the Lanao district in speaking of the upland of Mindanao. It is the territory bounded on the west by a line from Pangil to Illana Bay, on the north by Iligan Bay, on the south by Illana Bay, and on the east by the Kalintang Range and the hills of the western part of Bukidnon. The country rises gradually from Pangil Bay to the irregular group of mountains to the west of Lake Lanao. The lake itself is 670.5 meters above sea-level. A range varying from 760 meters to nearly 2,400 meters in height is located to the east of Lake Lanao. The country north and south drops off gradually from the lake to the sea.

Geology.—As far as I know from my own observations (having crossed this region from east to west and north to south), very few outcrops other than basalt exist. That this basalt is a blanket overlying sedimentaries is proved by the finding of sandstone on the east side of Lake Lanao; and again, at Parang, sedimentaries can be studied emerging at the edge of the basalt. Before discussing this basalt, it is better to consider the region beginning at Camp Overton. The military road starts from the latter and immediately climbs in a zigzag up the steep escarpment which faces the bay. For the first few hundred feet, it cuts through raised coral reefs and rubble limestone; then it passes out of the limestone, and from here to Lake Lanao is entirely on the

basalt. I have made no detailed study of the corals in these exposures, but they appear to be identical in species, certainly in genera, with those living in the sea immediately below.

The fall of the Agus is a magnificent spectacle. The water from the river drops 58.3 meters over a cliff of basalt to the gorge below. The principal part of the formation is a hard, olivine basalt with a tendency to columnar jointing. In the vesicular spaces there are white to greenish-yellow minerals with radial structure, some rays being over a centimeter in length. This mineral is usually one of the zeolites. Calcite is found in some of the specimens.

The formation changes rather sharply to an agglomerate in which are numerous boulders about half-way down the side of the gorge. The lower part of the formation is very porous and water can be noted issuing in little streams from many points in the side of the cliff.

Under the microscope the rock is seen to consist of the following principal minerals: labradorite feldspar, rhombic pyroxene, olivine, and magnetite. Some of the plagioclases are more than 5 millimeters in length. The pyroxenes are almost as large. The ground-mass consists of an ophitic mat of well defined, lath-shaped plagioclases, among which are scattered roundish grains of pyroxene, olivine, and magnetite. The rock at Mataling Falls south of Lake Lanao is of very much the same character.

I have already stated that I found one outcrop of sandstone near the Malaig River, which drains Lake Budig and flows into Lake Lanao. This sandstone was very much weathered and very closely resembled those overlying the coal in Cebú. It is not at all improbable that drilling at this point would reveal the coal measures below the level of the lake.

I made a trip in 1906 from Iligan into the hills southeast for a distance of about fifteen kilometers. Here I found andesitic agglomerate, and in the beds of the streams I picked up many pebbles of schist which must have been brought down from the hills on the boundary line between Lanao and Bukidnon. About two kilometers from Iligan I saw a little residual limestone from which I procured the fossil *Turbo borneënsis* Bttg.

The traveller, after leaving Mataling Falls, very soon passes into an extensive deposit of bluish-gray volcanic ash. This continues to Malabang on the coast.

Putting all of these facts together, I believe that the stratigraphy of Lanao is much the same as that of the Zamboanga district. At the base we have diorite as witnessed by the diorite pebbles in the Iligan River; above this is sericite and chlorite schist, then sandstone, and probably the whole coal measure series, which, however, may prove to be contemporaneous with the schists; and finally, piedmont deposits around the border of Lake Lanao, and those along the lower reaches of the river.

Economic.—This country is in such a disturbed condition that very little prospecting has been done. While at Marahui on the north coast of Lake Lanao, I heard reports of copper in the Taraca River. Mr. Ickis and I visited the Taraca River country and panned in the lower reaches of the stream without success, finding neither gold nor copper. The turbulent state of the Moros prevented our following this stream much farther than the limits of the jurisdiction of the *datu* with whom we stayed, and to one who knows anything of this district at all, this means that we did not get very far. Mr. Ickis was working toward this country, approaching it from the Agus River, when he was killed in the Subprovince of Bukidnon. I also heard reports of gold prospects east of Pantar, but they were not being worked at the time we were there and we were advised by the military authorities not to attempt to visit the locality. The only deposit of probable economic value which I have encountered in this district, so far, is the volcanic ash between Mataling Falls and Malabang. The Japanese have been fairly successful in the use of volcanic ash mixed with Portland cement and the same might be done here. Investigations are now being carried on in the chemical laboratory of the Bureau of Science with a view to utilizing the Malabang deposits.⁴ At Malabang a series of springs of very fine cold water issues from the more porous strata of this ash.

I have no doubt but that exploration in the Kalintang Range will bring to light some interesting geologic facts and possibly some of economic importance, but for the present it is *terra incognita*.

Before closing the discussion of the Lanao district I desire to refer to the possibility of utilizing the Agus Falls for power. Fairly accurate measurements have been taken of the amount of water passing under Pantar bridge so that we now know approximately the available horsepower. An engineer from the Bureau of Public Works has found that there are 40,000 electric horsepower available here at all seasons. I know the army engineers have calculated the possibility of utilizing this power for lighting the military posts from Camp Overton to Malabang, and also of running an electric line between these two stations. This upland district, in view of its water power, the wonderful agricultural possibilities, and the bracing climate, will one day be peopled by thousands of white men.

Soil.—As the underlying rock is largely basalt, the soil is naturally rich in iron. It is heavy and quite red when exposed. There is scarcely any timber left in this upland country save in the ranges to the east and south of the lake. I should look upon it first of all as an excellent cattle country and also especially adapted to coffee growing.

⁴ Mr. Reibling of the Bureau of Science found that this ash could be used to replace Portland cement to a large extent. It possesses good cementing qualities.

THE COTABATO DISTRICT.

The Cotabato district lies between that of Lanao and the Tiruray Tableland. It receives its name from the town of Cotabato, which is situated near the mouth of the Rio Grande. Physiographically it is largely made up of bottom lands along the Rio Grande. A portion of this bottom land is under water, a large area being covered by Lakes Liguasan and Buluan. The moderately elevated hill country begins on the slopes of the Kalintang Range and extends south to the river. The Rio Grande rises in the Subprovince of Bukidnon and flows south in a tortuous course almost to Lake Liguasan. There it turns at right angles and flows to the west into Illana Bay.

Little is known geologically about the country between the Kalintang Mountains and the Cotabato River. The United States Army engineers have made an excellent topographic map of this region, which has been incorporated in a large map of Mindanao published with this article. On the trail between Parang and Cotabato I saw something of the formation at the extreme western part of this district, and from an examination of the topographic maps, and from what I saw at Fort Pikit, about 160 kilometers to the east and in the center of this district, I believe that the low hills to the north of the Rio Grande are largely sedimentary: sandstones and shales capped with limestones. At Lake Balut, a short distance south of Parang, I found sandstone and shale beds varying in thickness from 30 centimeters to 1 meter, showing sections of small anticlines and synclines; farther south in the hills just north of the Cotabato Valley I encountered a section showing these beds dipping towards the valley with a slight angle, and still farther south some very much exposed gravel beds dipping 27° to the south. The sandstone and shales with limestone capping, outcrop again in a low hill at Reina Regente, and I once more met with these formations at Pikit, which stands on another small hill. As it seems, the Valley of the Cotabato is synclinal and not river-cut. I do not know how these formations dip on the south side of the river, but should expect them to incline to the north. I saw no igneous rock in this district, save near Parang, in Muan Creek, where we have the following section: at the base, diorite with an undulatory surface; above this, shales and sandstone in more or less thin beds; and above this, a sheet of basalt. The trail runs for a short distance just south of Parang along the edge of this lava flow, and black, carbonaceous shales, containing some fossils, can be seen outcropping. Whether or not there is coal below can only be determined by sinking a shaft or by drilling. It seems that the southern limit of the lava flow is at this point, as I found no more basalt in the Cotabato District, nor more volcanic rock of any kind until we got well up the Kabakan River very close to the Matutan Range, which is the eastern boundary of the district.

An oil seep is reported near Kudarangan; however, I have not seen it. It is not at all improbable that oil may occur in the sedimentaries of this valley. The conditions for artesian water are certainly favorable, as the sandstone would make an excellent water bearing stratum.

I have no information regarding economic deposits in this district. Prospecting at some future date, when the country is more settled, will doubtless reveal many valuable deposits of which we know nothing at the present time. The limestones and clays near Cotabato may possibly be utilized at some future date for making cement. The limestone is very pure, but no analyses have as yet been made of the clay. This is essentially an agricultural district and should develop into one of the most productive parts of Mindanao.

The limestone in Constabulary Hill is very fine, with very little magnesia and fairly white, inclined to be slightly pinkish. It contains numerous recent marine fossil shells. Among them are the following genera: *Pecten*, *Conus*, *Oliva*, *Turbo*, and *Cypræa*.

Soil.—As most of this district is covered with transported soil, the rich alluvium of the Rio Grande, there can be no richer agricultural tracts in the Island of Mindanao, and it should be capable of growing almost any kind of tropical crops.

THE TIRURAY DISTRICT.

Very little is known of the geology of this region, the only Government officials who have crossed the country being Lieutenant Van Horn, 17th Infantry, and Mr. E. B. Christie, ethnologist of the Bureau of Science. This was in 1902. Lieutenant Van Horn's report shows that the country is exceedingly rugged, there being possibly more than one distinct mountain range between the Cotabato River and the coast. Very few people live in this region and they are of the lowest station in life. Some of the peaks in the central part of the district, particularly Mount Lubuagan, 1,220 meters, may be old volcanic cones.

THE APO DISTRICT.

An irregular and interrupted chain of old volcanoes is situated to the east of the Cotabato district. Mount Apo, approximately in the center of the region, is dominant. Mount Matutan, about eighty kilometers to the south, and Mount Magolo between the latter and Apo, are other prominent peaks. The range to the north of Mount Apo is still unexplored, only one white man, to my knowledge, Mr. Jetar, having ever crossed it. On our march from the junction of the Rio Grande to the Kabakan River south of Mount Apo and to Digos on the Gulf of Davao, we were traveling continually in jungle where we had very little opportunity for studying the formations. Occasionally, we saw very small outcrops in the stream beds but no large sections or extended exposures. The formation is largely sandstone, with andesite

spread over much of the country. A number of low hills, quite far apart, are encountered just before the Apo Range is reached. These are marked on the map as the Matutan Range. Neither of these ranges is so well defined as is usually represented on the maps. In fact, it is possible to go from Cotabato to Davao without reaching an elevation higher than 610 meters.

There is a sharp definition between the peoples, and also the vegetation on the two sides of the Matutan Range. West of it are Moros. The country is heavily forested and very wet at certain seasons of the year. East of it the Moros disappear, but a number of related tribes, such as the Bagobos, Manobos, and Atas, are present. The vegetation becomes more scanty, the trees smaller, there is no underbrush, and the climate generally is much drier. We could not see Mount Apo in passing along its base because of the constant clouds enveloping the peak. In fact, from the time we left Cotabato until we reached Digos, ten days later, we had not a single glimpse of the mountain.

The following hints may be of use to prospective climbers of Mount Apo. The best place to start is from Daron. A Spaniard, by the name of Gregorio Palacio, who lives here, will assist travelers in obtaining Bagobo *cargadores*. It is best to leave this place about 6 or 7 o'clock in the morning. About noon, the house of Tongkaling, the chief of the Bagobos, is reached. Here a rest should be taken, continuing the journey on the next morning. Tadayay can be reached at noon by fast traveling. The trip from Tadayay to Major Mearn's camp at 1830 meters is very hard and will require a whole day. Here the base camp should be made. The trip from this point to the summit will require the greater part of the forenoon.

Mount Apo is in a cluster of peaks. I have already mentioned its general appearance in a previous article. I consider the present peak of Apo as produced by the erosion of a stock. The circular depression at the top is not necessarily a crater; the main mass of this cluster is to the northeast. The lines resembling bedding planes in the photograph (see Plate I) are flow lines. The rock constituting the peak of Apo is a flow of andesite porphyry, while that coming from the large crater to the northeast is andesite breccia. One phase of this rock found at the summit, is an augite andesite. The principal phenocrysts are large, glassy, though much corroded, plagioclases and colorless augites, with a small amount of biotite mica. The ground-mass, for the most part, is fine-grained with small fragments of feldsparpyroxene and magnetite scattered about.

In ascending this mountain, we passed three fumaroles at an elevation of about 2,120 meters; these are located along a deep crevasse which cleaves the southeast side of Apo. Another fumarole is found about one-half kilometer farther to the west. They are all very small, the openings being only a few centimeters in diameter; steam and sulphur fumes issue to a height of several meters with considerable noise. A

small cone of sulphur, in some cases a meter high, has formed around each vent. The sulphur is quite pure and of a beautiful yellow color, but I doubt if there is any commercial quantity of it; however, if there should be any considerable amount of the element buried or otherwise concealed by the weathered rock, in my opinion it can not be transported to the coast with any reasonable profit; in fact, it took our party three days of most strenuous climbing to reach this point on the mountain. A cableway might be erected, but at considerable cost. A little lake which rests on a shelf, or hanging valley, lies 450 to 600 meters below the summit of the north side of the mountain, but this probably exists only in wet weather. The top of Mount Apo is exceedingly rugged and covered with a scattered growth of blueberry bushes with very much twisted and stunted branches. This makes excellent firewood. Water usually stands in the circular depression just below the summit; this, although slightly salty, can be used after boiling.

My determination of the elevation of this mountain was made by hypsometer and is calculated to be 2,955.0 meters. The elevation obtained by the Spanish Survey was 3,145 meters. The recent geodetic work in that region carried on by the United States Coast and Geodetic Survey has given the altitude at 2,912 meters which proves that the hypsometer is quite accurate within 30 or 40 meters, probably much more accurate than a mercurial barometer and certainly far more so than an aneroid.

The difference in the character of the material on Mounts Apo and Pumantigan is well seen in the cañon of the Cibulan River. The formation here is a volcanic agglomerate, the rock being andesite, but in irregular boulders in a volcanic matrix. In one place where we stopped, the cañon is about 300 meters deep. There is an andesite conglomerate below which changes above into a solid flow of andesite. I suppose these zones alternate many times before the top of the cañon is reached. It seems very evident that there have been one or more tremendous explosions from the crater, of which Mounts Culelan and Pumantigan are the highest points.

I know of no economic deposits in this district, but the country is practically unprospected.

On April 28, 1911, Major E. R. Heiberg, governor of the Cotabato District, and party made the ascent of Mount Matutum, the next highest point in Mindanao, and which is situated between Mount Apo and Sarangani Bay. He found the elevation to be 7,880 feet (2,872 meters). Samples collected from a point of about 2,000 meters elevation, and submitted to me, have been classified as andesite.

Major Heiberg says in his report:

The peak is perhaps twenty feet in diameter and (with the exception of some scrub growth about six feet high) was, fortunately for us, quite bare, enabling

us to obtain an unrestricted view in every direction whenever the floating clouds below permitted. I had taken a large camera along, but was forced to leave it behind with the cargadores.

The perimeter of the extinct crater consists of four distinct peaks (one double), and averages about 350 yards in diameter. Carter and I made several attempts to descend into the crater, but finally gave up on account of its precipitous sides, the ropes I had brought along being abandoned when the cargadores gave out. We were enabled, however, to get a good view of it, and to observe that every portion is covered with the same peculiar dense growth described above. It is about 400 feet deep, and apparently three gorges which cut in between peaks prevent the formation of the lake containing deep-sea fish and white crocodiles which the legends of the superstitious Bilanes described. The volcano has been extinct (the literal translation of Matutum is "has burnt" or "fire out") for a century at least, although Lieutenant Mosher reported from Makar, under date of March 31, 1911, that, "on March 6th severe earthquakes were felt at about 11.30 p. m.; the following day, March 7th, Mount Matutum was smoking freely. Severe earthquakes were again experienced on the 22d." Just before we left, a large fire was built, the smoke from which, as we learned afterwards, was seen for many a mile. There is entire absence of rock on the very top, and all of the cone above approximately 6,000 feet elevation (except, of course, the vertical and overhanging walls) is covered with a peculiar vegetable loam. The huge outcroppings of rock—the precipices heretofore mentioned—are in two different colors, gray and red; both resembled granite (andesite) in appearance, but the gray is quite soft and not unlike pumice.

I suspect that Major Heiberg's figures are too low. He does not state whether he made any correction for the temperature of the air. If not, the more correct figure would be somewhere in the neighborhood of 2,900 meters.

Samal Island.—I have never been on this island but have a specimen of limestone which is said by Doctor Whitford, of the Bureau of Forestry, to form the capping of many of the higher points of the island. This limestone is white and quite pure.

THE AGUSAN DISTRICT.

The district of Agusan lies between the Apo Range and the eastern Cordillera. Davao is the principal town in its southern part and is the headquarters for the numerous hemp plantations bordering on the gulf of the same name. My own knowledge of this region ends with Davao, as at this point I left the exploring party. The town is on a narrow stretch of coastal plain between the Davao and the Lasan Rivers. Remnants of what appear to be marine terraces, although they may be entirely river formations, occur a short distance back of the settlement. There is one distinct terrace which is from 15 to 30 meters above the sea. I saw no fresh rock exposures, but the streams are full of pebbles, mainly of andesite, which evidently have been brought down from the Apo Range. Our geologic knowledge of Agusan Province consists almost entirely of observations by Messrs. Goodman and Ickis, who made the trip from Davao to Butuan overland. Mr. Goodman's

work has already been published in the first part of *The Reconnaissance of Mindanao and Sulu*.⁵

In this paper I shall add some translations by myself of the French notes by Montano who was in the Philippines from 1879 to 1881. In his report to the Minister of Public Instruction of France,⁶ Montano paid some attention to the geology of Mindanao, as follows:

All the facts which I have been able to observe in the interior and along the coast of the eastern part of Mindanao tend to prove that this region has emerged for the most part since the older epochs, or has undergone in the Miocene epoch an uplift which continues to this day. In following the course of the Sahug River, one can not at first have any idea of the geologic constitution of the soil, because in the lower reaches of the river there is a deposit covered with a thick bed of humus. Higher up, the bed of the river is less deep and shows a number of rapids formed by considerable blocks of rock. The rocks which constitute these outcrops belong to several species, quartz porphyry, (porphyry petrosiliceux), melaphyre and compact white and crystalline limestone. At 7° 40' north latitude, that is to say, about 35 kilometers in a direct line from the Gulf of Davao, the bed of the Sahug River is covered with enormous blocks of corals, which, according to the section I secured belong to the genus *Astræa*, very much like species now living in the Gulf of Davao. At several points where I could make out the composition of the mountains, these are formed of calcareous terraces, which appear to be horizontally stratified. In the center of Mindanao, Mount Hoagusan separates the basin of the Sahug from that of the Agusan which empties into Butuan Bay in the northern part of the island. Tubuan, an affluent of the Agusan, has its source on Mount Hoagusan at about 270 meters altitude. At this point one finds melaphyres. The banks of the stream show some beds of plastic clay with concordant stratification, dipping to the north at an angle of 45°. The larger part of the stream bed is formed very extensively of calcareous terrane, which at several points comes up in vertical masses from 20 to 40 meters in height. Upon the right bank of the Agusan River north of Lake Dagun, or Linao, about equally distant from the Gulf of Davao and Buluan Bay, is Mount Banauan, the altitude of which is 240 meters above the level of the sea and approximately 210 meters above the plain, which extends from its foot towards the south. It seems entirely formed of andesite which occurs in blocks of from 10 to 20 cubic meters. This same rock, though altered, is found in the River Banauan, which flows at the foot of the mountain. The andesites have been analyzed by Monsieur Ch. Velain, *Maitre de Conférences* at the Sorbonne.

The banks of the Agusan River from Mount Hoagusan to the sea are covered with forest and hence still less is known of the nature of the rocks lying below. Near the confluence of the Mahassan upon the right bank of the river, there is a promontory of some meters elevation which is made up of beds of stratified clay dipping 45° to the west. Between Las Ævis and Butuan the left bank is made up of altered diorite in *peperin* (tuff), stratified and dipping to the east at an angle of 20°.

The Agusan district, then, consists of two principal divisions: The southern part, which is mountainous and in which the streams are swift and full of rapids; and the northern, which is almost entirely plain,

⁵ *This Journal*, Sec. A (1909), 3, 6. ⁶ *Une Mission aux Iles Philippines*.

with large, more or less sluggish streams and few rock exposures. Some fossils which Mr. Goodman collected at Maasin in a recent marl have been examined by me. They are all extremely recent and marine, showing that the sea in Pleistocene times came up as far as this point, that is, to the southern part of the lakes.

Mr. Goodman says:⁷

An estuary leading into a small pond which drains into the Agusan is situated at a place called Maasin, about 3 kilometers south of Vuela. An outcrop of soft, blue shale, containing a large variety of fossil shells in an excellent state of preservation occurs on the west bank of this estuary. These fossils as well as those collected at Tagusap and other places, have been sent to Dr. Smith at Leyden, Holland, for study and comparison.

They were also found at San Rafael on this river. Some of the species are *Venus squamosa* Lam., *Tagalus coarctatus* Gm., *Arca nodosa* K. Mart., *Ranalla subgranosa* Beck., *Turritella cinquelifera* Sow.

I know of no developed economic deposits in this district. However, gold is reported from several branches of the Agusan River and possibly this will be fruitful dredging ground some day. Mr. Garvan, of the division of ethnology of the Bureau of Science, who is thoroughly acquainted with this region and its inhabitants, informs me that gold is panned in paying quantities by the natives in the district of Cansuran and neighboring mountains to the west, and in the headwaters of the Solibao, Adlayan, Bunauan, and Hinatuan Rivers. Gold is reported also from the following rivers: Bilay, Masago, Ua-Ua, Culi, and the Quila near Guadalupe. Coal has been found on the Ua-Ua, Culi, and Bunauan Rivers.

There are practically no roads in the subprovince, and this, coupled with the lack of rock exposures, makes it extremely unlikely that the Agusan district in the northern part, at least, will for some time to come be of any importance as a producer of mineral. There should be some excellent transported clays in this valley, which might be utilized.

THE SURIGAO DISTRICT.

I include in the Surigao district the cordillera in the extreme eastern part of the Island of Mindanao. Our knowledge of the geology of the rocks of this region is extremely limited. Goodman has crossed it in the vicinity of Mati at the head of Pujada Bay. He found the ridge to have a core of igneous rock which had undergone some metamorphism. The original, unaltered diabase, which is the most common rock encountered, presents a typical ophitic structure and contains in addition to the feldspar and ferromagnesium minerals, a considerable proportion of secondary quartz and microscopic crystals of apatite. Goodman also

⁷ *This Journal*, Sec. A (1908), 3, 509.

found a chloritic schist, reddish-brown in megascopic specimens, and containing a large amount of secondary quartz. He thought it to be an alteration product of the original diabase. He goes on to say that both coasts of the peninsula are composed of sedimentary strata. A pink limestone, intersected by numerous veinlets of calcite, rests on the west flank of the igneous intrusion, while the east coast is mainly conglomerate and brown shale. These beds at Mount Badas attain a thickness of over 180 meters and dip about 45° toward the southwest. In the vicinity of Mount Mayo the formation is sedimentary. Mr. Goodman found the conglomerate here dipping at an angle of approximately 30° to the east. The boulders in the conglomerate are igneous. At a place called Lucatan, about midway between Mayo Bay and the town of Tarragona, the formation changes from conglomerate to the limestone lying above. It is an elevated reef. This limestone lies unconformably above the conglomerate.

Goodman found a seam of coal about 85 centimeters thick on the south bank of Cobatoc Creek about 9 kilometers north of the town of Tarragona. The seam dips at an angle of about 15° south 50° east. A conglomerate of coarse sandstone immediately underlies it, while above is a soft, brown shale which, in turn, is overlaid by an impure limestone. This coal in general appearance is much like the other coals of the islands; it is sub-bituminous. Goodman believes that this is a most favorable point for further prospecting.

We have very little information about the east coast. A set of specimens given me by Father Sanchez, a Jesuit missionary who was stationed at Baganga for some time, includes orbitoidal limestone of a beautiful pinkish color, evidently the same formation found by Goodman farther south, specimens of silicified wood and a rock made up of a large number of coral stems all completely silicified. A number of specimens which simulate the petrified bones from the flipper of some cetacean also appear in the collection. The likeness is very remarkable, but these specimens are probably not petrified bones, the phenomenon being due simply to the wearing of alternate hard and soft layers from a calcareous formation. It is evident that there is considerable residual limestone left on the hill tops in this cordillera. Specimens of andesite are also to be found on the beach at Baganga.

The next point at which Goodman touched is Bislig, at the head of Bislig Bay. On his way across from Lake Linao to Bislig, he encountered much the same formation as he had seen farther south. He examined a coal deposit a short distance up the Bislig River, but was unable to learn much about it without a great deal of exploration. It is of considerable importance to know the mere fact that coal outcrops at two distant points on the east coast.

Montano has left a few notes regarding the east coast of Mindanao. He says:

At the center of the island between Bislig on the map shown and the Rio Simulao, a tributary of the Agusan, I crossed the Cordillera Central at an altitude of 130 meters by the passage of Mount Bucan, the formation of which is made up of a thick bed of brown clay, but at the foot and to the west of this mountain the Miaga, a tributary of the Simulao, has some cascades and rapids which reveal massive Miocene andesites of great thickness. The east coast of Mindanao between Bislig and Pugada Bay presents a succession of capes generally elevated and rounded and formed by the projecting spurs of the Cordillera Central. Between Bislig and Cateel upon this coast I collected some madrepores altered at the contact with serpentine. It is along this part of the coast that elevation seems to be most evident. Some large banks of madrepores rest above the level of the sea, occurring as large horizontal tables polished by the waves which the northeast winds raise above their normal height. These banks of madrepores are especially prominent between Cateel and Point Bagoso. They are without doubt of the same origin as those produced by the waves between Bislig and Cateel, which in bad weather are dangerous to approach. These rock breakers form a cordon parallel to the bank upon which the sea dashes with fury, although a relative calm exists in the zone which they protect. Particularly along this coast, and even more so between Point Bagoso and Pugada Bay, the evidences of uplift are manifest. One finds there all gradations between the broken madrepores mixed with humus upon the summits of the capes, and those which, raised at the edge of the coast, have lost their organic material only recently. Upon the same coast one finds at every step some conglomerates which are formed by a mixture of sand and debris of ground-up molluscs and madrepores. In the Gulf of Mayo, near the Bay of Pugada, the cliffs of Butuan, which are quite extensive and have an elevation of from 20 to 60 meters, are formed of a pudding stone in which molluscs abound similar to those which live to-day in the gulf. I have collected some madrepores and some gypsum mixed with pyrites of iron upon the coast of the Bay of Pugada, and upon the ridge which separates it from the Gulf of Davao, some brecciated quartz.

Economic.—Much more has been done in the way of prospecting near the northern part of the district of Surigao, but we have still very meager geologic details regarding the country. Goodman, formerly mining engineer in the Bureau of Science, has written concerning the gold fields of the Surigao Peninsula from the view of the engineer. This report was published in 1909 in the second bulletin of the Mineral Resources of the Philippine Islands.⁸

The country rock of the region is andesite intersected by a system of veins running in general about north 55° east and dipping 60° to 70° toward the southeast. Many of these veins are mere quartz stringers less than one centimeter in thickness. In general, the walls of these stringers have become silicified to a greater or less extent, making the limits of the mineralization very definite. Most of the prospecting work has been confined to the neighborhood of Placer on the east coast. In Goodman's opinion the best way to work this ground is by hydraulic

⁸ *Min. Resources P. I. Bur. Sci., Div. Min.* (1909), 40.

methods. Since his visit to this country an American miner has brought some rich ore to Manila which he states comes from a fairly wide lode which could be worked by the ordinary mining methods. The natives probably have worked here for centuries. In speaking of the native methods of mining, Goodman says that in four days of mining and one day spent in cleaning up the sluice, a native miner, assisted by his wife and two male helpers, washed approximately 7.5 cubic meters of gravel, cleaning up therefrom 260 grams of gold for which they received 15.60 pesos (7.80 dollars, United States currency), equivalent to about 2.08 pesos per cubic meter. This is extremely rich ground. I have marked the principal localities where gold has been found on the map accompanying this paper and have added Goodman's report as an appendix to my own.⁹

A letter from Reverend Francisco de P. Sanchez to the Rector of the Ateneo S. J., in Manila, dated May 16, 1887, gives some geological notes on Surigao, but as later writers have covered the territory more fully, I shall merely cite the reference.¹⁰

THE CAGAYAN DISTRICT.

There now remains to be considered the district of Cagayan. This is an irregular defined area, bounded on the west by Iligan Bay, on the north by Makahalar and Hingoog Bays and on the south by the upland country of the Cotabato district. A stretch of unknown country extends to the east of this district through which Ickis had traveled and concerning which he made notes just before his death. The district is marked physiographically by a very limited coastal plain, a rough but not very elevated interior, and a number of rivers, the Cagayan, Iponan, and Tagoloan, which head on the divide close to the Pulangui River. The country rock consists largely of sedimentaries and a schist formation partially overlain by andesite. I shall refer the reader to my translation of Abella's report of 1877 for a detailed account of this district.¹¹ This report deals with the high- and low-level placers of the Iponan, Cagayan, and Tagoloan Rivers. According to Abella, the country rock is largely a chlorite in which small stringers of quartz-bearing gold occur. These stringers are too small to be worked *per se*, but the concentrates which have been deposited along the rivers already named can be worked. The natives have worked these placer deposits probably for ages and have become so skillful that they are able to tell at just what depth they will get values. The work is fairly crude, and, briefly, is as follows:

A pit is dug until the formation termed *dugcalon* is reached. This consists of a yellow clay containing pebbles of quartz and erupted rock, some of great

⁹ In the last year there has been renewed activity in gold mining near Surigao and exceptionally fine samples of placer gold have been obtained.

¹⁰ Cartas de los PP. de Compañía de Jesus, Manila, (1887), 251.

¹¹ *Min. Resources P. I. Bur. Sci., Div. Min.* (1910), 62-71.

size; others small, of hematite or magnetite, termed *tonasi*. This is the pay streak and varies in depth from 1 to 5 meters. The method of operation is best told in Abella's own words as follows:

Method employed in the district for the recovery of the gold.—The method is in reality the same as that employed by the natives throughout the island for working the placers, and though quite simple it is very similar to that used even to this day in other countries, and reveals a certain knowledge of the rudimentary principles of mechanics which seems to corroborate the hypothesis of former Spanish work.

The exploitation is not continuous, as is usually the case in all classes of mining, but is confined exclusively to the rainy season, forming campaigns of work, or harvests (*cosechas*), if you wish to call them so, with long periods of rest.

Not only is the water valued for the washing and concentration of the ground, but also they employ it as a mover and worker in the excavation of the same, limiting the physical work to a primary preparation and then to aiding and guiding of the work done by the water.

In these places, in which by reason of being not too far from nor too much above the river, they suppose that the placer is rich enough to yield values, they sink a prospect pit called a *tujubs*. It is circular and about a meter in diameter. If iron implements are lacking, they use a section of cane or of *palma brava*, which they sharpen to suit the purpose. For the excavation of the ground they notch a bamboo pole after the fashion of a ladder, by means of which the earth in home-made baskets which they call *tuoyac* is brought to the surface. When the excavation reaches the *dugcalon* or pay streak they test the ground as they advance, washing it in the adjacent arroyo with the *bilingan*, already described, deciding from it whether it is worth while to explore farther in this place. If not sufficiently paying they open other *tujubs* or *pozitos*, until they find a place whose richness satisfies them. When this point has been reached, and sometimes before the preliminary investigation has been made, a partnership is formed for the exploiting, or the same prospector forms a contract with a certain number of workers, who are also his associates. Since they are obliged to maintain themselves and keep a lookout in the course of the work, they share in the profits, a half or two-thirds, depending upon the district in which they work.

Organized in this manner, or in squads of workers, and having chosen a favorable place for operation, they seek at a point 100 or 200 meters from this and on a higher level, a spot where a reservoir for the water from the neighboring hill, having a capacity of 10 to 25 cubic meters and a depth of 30 to 40 cubic meters, can be located. Leading out from the reservoir, they open a canal 30 to 40 meters deep which they prolong, and skirting the slope of the hill nearest, oftentimes as much as 800 to 1,000 meters from the said reservoir, collecting in its course by so doing not only the rain water which falls on the upper part of the hill, but also that from the arroyos which it encounters in passing, and conducting it to the reservoir. If in its course they encounter any sudden depression of the ground they bridge it by a curious aqueduct made of canes and *palma brava*. They then place the reservoir in communication with the point or points which they have chosen for commencing operations by means of other canals, whose junction with the reservoir is closed by means of gates made of cane and brush, in order to gauge the quantity of water necessary in each case and to cut off the flow at the right time. This having been done in the rainy season and the reservoir filled with water, they open the gates, which I have just mentioned, with two or three men placed at the point or points to be washed, provided with implements analagous to those which I have indicated above, though sharper, and in shape not unlike very short oars. With these they accele-

rate the corrosive and dissolving power of the water which pours in with great velocity upon the place which they have chosen so that a kind of shaft is rapidly sunk till it reaches the barren ground upon which the alluvion rests. At the same time, while the water is loosening up the pieces and lumps, the workers remove the mud thus produced and throw it out continuously upon the surface, in order that the rich sands may be deposited and the clay and barren matter may be washed out by the stream. In this manner, the advancing excavation reaches a depth equal to that of the thickness of the alluvion, pushing gradually forward horizontally along the course of the canal which leads to the reservoir. In order that the advance may be slow and thus permit of exploiting the placer in all directions they open to the right and left of the main canal a number of cross cuts, which conducting the water from the sides, make other lateral workings which as they advance give a more or less circular form to the whole.

The large boulders encountered in the lower part of the alluvion they sort out by hand and use for making the walls of the run-off after it has been used. The excavation which results, whether consisting of one trench or of several, is called in the district *banlasan*. This part of the work has certain similarities to the method which the washers with the *gandingas* use in the Province of Mediodia in Spain, in the sluice boxes called *rollos* or *arollos*. Nevertheless, the *banlasan* is larger and less skillfully made than the *rollos*, and they work with a greater quantity of water and with a greater velocity.

Once or twice a week, depending upon the richness of the placer, when the upper part of each trench is sufficiently full of rich sands, they close the gates of the reservoir and give each trough a chance to dry out. They then take these sands to the bank of the reservoir and by means of the *bilingan* already described in the river washings, concentrate and separate the quartz, zircon, etc., from the fairly clean gold dust and apportion as indicated above.

To summarize, this proceeding has four phases distinct as to order and object.

(1) *Investigation* of the deposit by means of *tujubs*, not always necessary, as for example when by other indications or by known signs they know beforehand that the placer is rich in the part they expect to work. (2) *Preparation* for the work by the construction of a canal, reservoir, and all the other work. (3) *Concentration* of the alluvial ground or the exploitation proper of the deposit, by means of the work in the *banlasan*. (4) *The cleaning up (depuracion)* of the sands by hand washing with the *bilingan* finally obtaining the gold free.

In another paper published about the same time as the report just referred to,¹² Abella gives some further information regarding the geology of this country. He refers to a number of formations which I shall take up briefly.

He noted a considerable limestone formation which apparently is overlaid by a conglomerate with a calcareous matrix. This conglomerate he calls *gonfolita* and above this *gonfolita* he encountered a yellow marl, fairly loose and quite like that which covers the slopes of the divide between the Cagayan and Iponan Rivers. This marl is probably the result of the weathering of the matrix of the conglomerate. The pebbles of this conglomerate, according to Abella, are serpentine, argillaceous slates, and trachytic rocks of many types. He also found an arkose

¹² Itinerarios Geológicos. Observaciones tomados al paso en los viajes hechos a las comarcas auríferas de Misamis.

(*maciño*) and an impure sandstone formation which he termed *molasa*. The limestone of this country is quite cavernous and has abundant stalagmites and stalactites. Abella found he was unable to determine specifically one fossil which he found, but he believed it to belong to the genus *Turbinolia*. On the basis of this and lithologic evidence, he classified the limestone marls, conglomerates, etc. of this region as Miocene, which I think is quite reasonable. Upon the hills near the *barrios* of Munique, Quiliut, and Tagiptip, he found some boulders which are white and of cellular structure. At first he thought these were limestone, but on closer examination they appeared to be of a feldspathic material with secondary crystallization in the pore spaces, probably zeolites, and with all the other characteristics of modern volcanic rocks. To explain the presence of these rocks, Abella thought that in the mountain chain to the south and southwest there existed a crater which at a former period threw these volcanic bombs out over the country. He also noted a very important feature, namely, that there is a lineal regularity in the volcanic manifestations, as the line connecting the recent volcano of Camiguin and of Apo and Batulong passes through this region, and he thought this confirmed his supposition.

Abella's general conclusions regarding this region were as follows:

GENERAL DEDUCTIONS.

As a result of the observations which I have just given, there appear to be only three perfectly distinct formations considered petrographically and stratigraphically, shales more or less metamorphosed, marls, and alluvial deposits. Among the last mentioned, one distinguishes between the auriferous and the barren or poor, not only by its different composition and richness, but especially by the relative age of the two deposits, confirmed by the examination of the beds of the streams which cut across the placers.

In reality, however closely the ancient streams which produced the placers followed, with slight variations, the present river valleys, tracing out, so to speak, the modern hydrography, it is certain that this alluvial action has become much weaker, and I have no doubt but that the surface streams have been greatly reduced in volume and that the earlier deposits in part have been destroyed by the erosion of the water carried in the present channels, the sands of which also contain gold, but from a source and in occurrence very different from the ancient placers. The gold which one finds in these comes from deposits in rock which must be situated in the interior, and upon which the alluvial action worked with energy, loosening, transporting, and depositing its materials to a greater or less distance. The gold contained in the beds of the present rivers has come from the destruction which they produced and still produce in the auriferous alluvions deposited previously, and only, perchance, in the highest parts of the present streams of greater importance is there to-day even a small amount of erosive action on the rock deposits cited.

Therefore, I believe there are sufficient reasons for making this distinction between those which can be called *ancient*, the primitive placers, and those which I should designate as *recent*, which have formed and continue to form the beds, valleys, and beaches of the present topography of the country.

As the greater part of the auriferous alluvions lie above the deposits overlying

the marl-limestone formation, which I have classified as middle Tertiary, and these in turn upon formations still older, it results that the placers must have been formed after the Miocene period and before the present formation.

I have already said that the formations which are the most extensively developed in the whole district, at least provisionally, could be considered as belonging to the middle Tertiary, not simply because of the doubtful determination of the genus *Turbinolia*, but more by reason of their petrographic characteristics and their stratigraphic position.

With regard to the slaty formation which is more or less metamorphosed, as it occurs in many places, it is difficult to assign any age to it which would not be more or less subject to error, because of the insufficient lithologic data I have been able to gather. However, I can be sure that it is the oldest formation I have crossed, but I can not be more exact, and I leave the question unanswered until an opportunity for making more detailed observations can be found or until I shall have had greater experience in these studies.

During the reconnaissance here mentioned and others of less importance which I have had occasion to make, I have seen no deposits other than the auriferous ones I have described in detail in the report, and I have had only reports of some beds of coal which they told me had been discovered to the southeast of Nauan, a one- or two-day trip from this town. Although I did not finally see samples which they promised to show me, from the description they gave me of it and the adjacent terrain, I corroborated what I had suspected, namely that this coal occurs in the Miocene formation which extends as far as that locality, and because of this I believe it must be a lignite and that but for this it might be of great future use.

Moreover, they have indicated to me in a vague sort of way that to the west of Iligan the existence of plumbiferous and pyritiferous minerals which, to be exact, occur in localities little known and which are not very safe, in the dangerous vicinity of the Moros which live around Iligan.

Some occurrences of gold have been reported to the southeast of Nauan, but they have not been investigated by Abella or any of the later engineers, except Mr. J. Clayton Nichols who visited this region in 1900 in a private capacity. His report²² has added very little new information about the geology. His conclusions regarding the possibilities for mining are of interest. He says that the Iponan River is an ideal stream upon which to work a dredge. He also makes some observations on the climate as follows:

At no season of the year is there a scarcity of water and during a few days only is the water so high as to interfere with operations. The working season is from one year's end to the other. Frost is unknown in Mindanao. The climate is delightful and the country is healthful and fertile. Parts of it, especially the lower Iponan Valley, are thickly inhabited. Native labor is plentiful at a low rate of wages. Tropical fruits, corn, coconuts, rice, vegetables, and sugar are plentiful and cheap.

The gold production of this region can only be estimated, as the natives sell most of their winnings to local Chinese traders and it never passes through the hands of any officials. Eight thousand pesos are said to

²² The Gold Deposits of Pigtao, etc., *Trans. Am. Inst. of Min. Eng.* [1901], 31, 611.

have been taken from one hole and 5,000 from another. The owner of one of the mines said he had taken 2,000 tael (2,800¹⁴ pesos) from it in 16 years, but he did not state how many men he worked. The report of the Spanish Government gives the production for one year at 600 taels (840 pesos).

Ickis¹⁵ published a report interesting for the confirmatory evidence of vulcanism in this region and for the data he obtained regarding the country farther to the south in the vicinity of Sevilla, which is on the upper waters of the Pulangui much farther in the interior than either Abella or Nichols ever reached.

I have already discussed the physiography of the Tagoloan River in the chapter on that topic. The main point of interest in this connection is the fact that after the gorge of the Tagoloan is passed, some 25 kilometers back of Agusan, the country opens and is much gentler in topography.

Ickis found only alluvial land covered with *taláhíib* (*Saccharum spontaneum* L.) in the region of the Pulangui River. This land contains a great amount of gravel and, according to Ickis, is of considerable area. He thought that the country would be well adapted to dredging operations. He says:

The gravel beds along the Pulangui River are extensive, and promising colors were obtained by washing the surface near Sevilla in gold pans. It is believed that these gravels are worthy of careful investigation by prospectors who have testing machines, or who are equipped to sink test pits. The head waters of this river also afford a virgin field, since no prospector or miner has ever been known to visit the region. Gold is known to occur in the river gravels and the rock is of a nature favorable for the formation of mineral deposits. At the present time transportation is a difficult problem, but it is expected that a wagon road will soon be constructed from Agusan to the Pulangui River.¹⁶

Before closing the discussion concerning this district I will refer once more to Catarman Volcano on the Island of Camiguin.

The mountain and volcano of Catarman on the Island of Camiguin.—In Part II of this work I gave some excerpts from a report by Father Maso, S. J., relating to Catarman Volcano. Since the preparation of that manuscript some interesting water color sketches were found in Catarman by Mr. Dean C. Worcester, Secretary of the Interior, and kindly loaned to the Bureau of Science by him. These were made on the spot by an old Spanish resident (Plates III and IV).

I have only one sample of the rock from the mountain, collected by Mr. H. D. McCaskey, formerly chief of the Mining Bureau. The rock is a grayish, vesicular lava with numerous glassy feldspar and a few ferro-

¹⁴ This is taking the tael, a very variable unit, at 1.40 pesos.

¹⁵ *Min. Resources P. I., Bur. Sci., Div. Min.* (1907).

¹⁶ Three separate prospecting parties have recently set out for this district equipped with New Zealand boring machines.

magnesian phenocrysts. There are occasional holocrystalline patches to be seen in the rock.

Still another hand specimen is a hard, dense andesite which doubtless came from an older part of the mountain.

This brief summary gives our present knowledge of the geology of Mindanao. We have as yet only a reconnaissance of this vast region. It is hoped and fully expected that it will not be far behind the other parts of the Archipelago when it is once opened by energetic men who will unearth the riches so long buried.

THE SULU ARCHIPELAGO.

A host of small islands, rising above a bank which extends all the way to Borneo, lie southwest of the Zamboanga Peninsula and in the same tectonic line. The largest of these are Sulu, Tawi Tawi, Pangutaran, and Siasi. We have very little detailed knowledge of the geology of this group, chiefly because this is the home of a large part of the Moros with whom the Government, both Spanish and American, have always had trouble. There is very little published information concerning this region, and only two geologists have left us notes on the subject. Montano, whom I have already mentioned, devotes one paragraph to this Archipelago; it reads as follows:

The Archipelago of Sulu extends from Borneo to Mindanao in a chain of islands situated upon the summit of a submarine bank. Without doubt several of these islands with a slight elevation consist in great part of banks of corals which gradually reach the surface of the sea, and which, becoming covered with detritus of various kinds, are covered with vegetation. This is especially true of many islands, and notably of that of Sulu, which gives its name to the Archipelago. In the Island of Sulu I have not observed signs of a coral formation except upon the coast and it occurs here homogeneous and formed of a mixture of madrepores and mollusks. It seems to rest upon sand. Its upper level is raised about 2 meters above the highest tides. The mass of the island seems to be of volcanic structure. Some deep trenches opened in the hills near the Spanish village of Sulu (Jolo) show numerous blocks of lava containing pebbles. Some larger blocks of the same rock are scattered over the plain and are seen in abundance in the beds of the streams as well as near the ravines made by the rain which comes down from the summits of the island. Especially characteristic is the great development of weathered material covered with cogon prairies or forest which conceal the structure of the formation.

Guillemard,¹⁷ in his Cruise of the Marchesa, has written a very interesting general account of the crater lakes of Cagayan Sulu. He speaks of a number of circular basins which are filled with water and which he thinks represent the craters of extinct volcanoes. Beyond this he gives no geologic data, but he has published a map of the island with additions and corrections by Lieutenant Powell, Royal Navy, and

¹⁷ The Cruise of the Marchesa to Kamchatka and New Guinea. 2 ed. London (1889), 179-188.

himself. This map shows as many as 15 peaks in the interior, the highest of which is 253 meters, which evidently represent extinct volcanic vents, and in the southern part of the island are three almost circular depressions, two of which are entirely enclosed, and the third, Lake Jiwata, is connected with the sea by a small opening. In this opening are two or three islets and it is quite evident that this basin was also once entirely enclosed, the narrow rim of it having been broken through by the sea.

My own observations in Sulu consist of a trip across the Island of Sulu from the town of Jolo to Meimbun; the ascent of Mount Dajo; some reconnaissance on the outskirts of Jolo; a short trip of two or three miles on the coast of the Island of Siasi; a short excursion of a few hundred yards from the coast on the Island of Lapac; an ascent of the high peak on Bongao Island; and such observations as I could make from the launch which skirted many of the small islands as we went through the Archipelago.

The Island of Sulu, as far as I could see, is almost entirely blanketed by volcanic material, either basalt, tuff, or ash. I saw no active volcanoes in Sulu, but it is reported that there are hot springs at Si'it Lake. The island is studded with extinct or dormant cones, the most prominent of which, and at the same time the most interesting from an historic standpoint, is Bud Dajo, ten or eleven kilometers southeast of the town of Jolo. This is a beautiful cinder cone now covered with luxuriant vegetation. A photograph is shown in my first paper, Narrative of the Expedition.¹⁸ The diameter of the crater is about 480 meters. It is almost circular and is broken down on the southeast side, where a small stream issues. A spring, which feeds this stream, is located almost in the center of the crater. The panorama obtained from the rim is one of the most beautiful I have ever seen. Everywhere are extinct cones, the side of which are now covered either with forests or *cogon* grass, and in the valleys between are found many *haciendas* of tapioca. It would be extremely desirable to know the nature of the formation below the mantle of volcanic material. The streams as yet have not cut very extensively, so that we do not know just at what depth the sedimentary formations are to be found. However, should we not find sandstones and shales it is quite reasonable to suppose that drilling in the vicinity of Jolo would tap a loose formation of volcanic material which carries water. I know of no economic deposits being worked on this island.

The Island of Siasi is covered with a mantle of volcanic material weathered to a considerable depth. Lapac is the same. Tawi Tawi seems to be like the rest. Bongao Island, at the extreme southwest end of Tawi Tawi, is made up largely of tilted beds of sandstone and con-

¹⁸ *This Journal*, Sec. A (1908), 3, 473.

glomerate. Vertical jointing in Mount Vigia simulates the columnar jointing of basalt; it is only upon a close examination that the formation is found not to be volcanic. I ascended Mount Vigia and found it to be conglomerate from top to bottom. The matrix is a sandstone, very ferruginous in places, well stratified and dipping southwest at an angle of approximately 15° . The boulders of the conglomerate are andesite, varying in size from pebbles to masses weighing several tons. Just at the edge of the town and but a few feet from the sea, at an elevation of 12 to 15 meters, there is a small shell bank, partly coralline. The shells are very recent. With the exception of Mount Vigia, which owes its height to the resistant material in it, the island is very low.

I made the following notes while passing close to the Island of Tawi Tawi.

I saw no signs of vulcanism on the island. There are few high points; in fact, the sky line is much like that of northern Cebu. A forest fire in 1903 decimated the forest and now there is nothing but straggling timber and thick undergrowth. (We skirted the northern side of the island). Tawi Tawi Mountain may be volcanic, but old. A very white rock outcropping on the side of this mountain is seen with a glass. It may be limestone.

A few miles northwest of the town of Jolo are a number of islets which have peculiar profiles (Plate V). These islands are very low, for the most part with shallow depressions in the interior, sometimes dry and sometimes filled with water. They are largely composed of coral, but on Marongas Island there is an exposure of conglomerate which is cut by more or less vertical basalt dykes. These dykes vary from a few centimeters to a meter in width. On either side of the dykes the rock has been vitrified for several centimeters. An examination of the dyke rock under the microscope shows a very fine-grained lava with distinct flow lines and phenocrysts. The phenocrysts are olivine and plagioclase feldspar. The streaks, which have a fluxion arrangement, consist of a very dense cryptocrystalline mass in which innumerable minute magnetite grains occur. There is a rude parallelism of the crystals bordering these denser streaks. The rock is very vesicular in part. The hummocks on this island and several others are simply due to the hard conglomerate and dyke formations.

The history of the Archipelago briefly stated is as follows: A submarine bank, which may represent a buried mountain chain, rose slowly from the sea. Corals grew upon this, and at a number of points, flows of volcanic material penetrated and poured out over the country. The period of greatest activity was probably in the Pleistocene. There is little or no volcanic manifestation at present. The weathering of this volcanic material has produced a heavy and very ferruginous deposit not unlike the laterite of India. I know of no economic deposits being worked anywhere in the Sulu Archipelago.

In conclusion, I wish to call attention to text figure 1 wherein I have attempted to show the probable outline of Mindanao in early tertiary times. This is purely tentative.



Fig. 1.—Probable outline of Mindanao in late Tertiary times (represented by diagonal lines).

APPENDIX.

By MAURICE GOODMAN.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

Upon the completion of the reconnaissance from Davao to Butuan, I continued on my way to the mouth of the Tubay River, which empties into the sea at the town of Tubay on the eastern shore of Butuan Bay. The lower part of this river is a raging mountain stream containing numerous rapids, which add no little element of danger to the ordinary difficulties of rowing against a swift current. Near the coast I estimated our headway to be at the rate of about 1,700 meters per hour, but as we approached the junction with the Asiga River further progress was rendered extremely laborious and it was only with the assistance of some friendly Mangwangs that we made any headway whatever.

The Tubay River above the junction with the Asiga is as smooth as a pond and has scarcely any current. Gravel from below the junction, whether taken from the banks or from the river bed, gave three to eight colors to every pan. The gold is evidently brought down by the Asiga, the source of which lies east of Lake Mainit, and on the western slopes of the long mountain range extending from Surigao on the north to Cape San Agustin on the south. Numerous hornblende diorite boulders were observed in the Asiga, many of them heavily impregnated with iron and copper pyrites implying generous mineralization of the country traversed by this river. I believe that the region about the headwaters of the Asiga might well repay further prospecting for both copper and gold.

The banks of the Tubay River consist of metamorphic rocks, mostly chloritic schists. A finely laminated mica schist containing a large percentage of calcite (calc-schist) is also very abundant.

About six kilometers northeast of Santiago on the Tagbunuan Creek is an outcrop of a dark greenish sandstone, the basic fragments of which are very much weathered and serpentized. The banks are very steep at this point and have recently slid, covering the ground with a great mass of débris, but exposing in the solid formation several minute seams of coal, none of them more than one centimeter in thickness. The superstitious natives prize these black fragments for the medicinal properties they are supposed to possess. As I neither saw nor heard of any specimens larger than a walnut, I presume that no thicker seams than those I observed outcrop anywhere in the neighborhood, and this occurrence of coal therefore has no economic value.

The effects of regional metamorphism are well shown, not only by the folding and fracturing of the minute coal seams, but by the chemical composition of the coal itself. An analysis of the fragments showed the following composition:

	Per cent.
Water	8.10
Volatile combustible matter	22.95
Fixed carbon	55.29
Ash	13.66
Total	100.00

As compared with other Philippine coals, the percentage of water is somewhat lower, and that of ash somewhat higher than the average, but the greatest difference lies in the high ratio of fixed carbon to volatile constituents. The loss in volatile constituents with the corresponding increase in fixed carbon evidently is due to the intense pressure, accompanied no doubt by considerable heat, attendant upon the dynamic stresses engendered by the folding of the rock strata during some recent period. Further evidence of this metamorphism will be referred to later.

The upper portion of the sandstone in which the coal seams occur is a conglomerate of basic igneous rocks, the component pebbles of which are very much altered and serpentinized. Overlying this is a hard calcareous shale passing into a semi-crystalline limestone.

Gravel panned on the Asiga, just above its junction with the Tubay, showed no color, but this is probably due to the high velocity of the current at this point.

Above Santiago, the Tubay River has a very slow current, and an average width of about 30 meters. Narrow channels between floating islands of swamp growth alternate with miniature lakes 300 to 400 meters wide. In general, the west bank is high and wooded while the east bank is flat throughout and generally bordered by fresh water swamp.

The Tubay River may be considered as a channel draining Lake Mainit into Butuan Bay. This lake is almost circular and measures 9.5 to 10 kilometers in diameter. Only two towns are situated on its border, Jabonga on the south and at the head of the Tubay River, and Mainit on the north. A short distance north of the town of Mainit is a mountain rising prominently from the surrounding, comparatively level country. To judge from its geologic formation and its symmetrical slopes, Mount Mainit, or Saporga, as it is sometimes called, must be of volcanic origin.

Lake Mainit is frequently spoken of in the literature as a crater lake, mainly I suppose, because of its location, outline, and proximity to the extinct volcano Mainit. However, from my own observations I believe that the lake was caused by a subsidence of the submerged area, consequent upon the withdrawal of the material which went to make up Mount Mainit and other volcanic masses to the north. I did not visit the east shore, but Montano¹⁹ reports the presence of hot springs emanating from limestone strata, but I crossed the narrow ridge separating Lake Mainit from the Surigao Sea and there also I found nothing but stratified rocks in their original or metamorphosed condition. Most of them were chlorite-bearing schists or alteration products of the same. The original bedding planes are obscured by the new cleavage planes induced by dynamic pressure. In general, the direction of the cleavage planes is somewhat west of north, while their inclination is in both directions east and west. The east flank consists largely of red and brown slates finely laminated, and in places interleaved with white marble. Near the top of the ridge the proportion of calcite increases, and some fine pieces of marble are to be observed. Inclusions of a green micaceous mineral, probably chlorite, are very common. The slate is highly calcareous and is probably an alteration product of an impure argillaceous shale. It has a very fine and distinct cleavage, and if sufficient material

¹⁹ *Voyage aux Philippines et en Malaisie, Paris (1886), 314.*

can be found and conditions of demand and transportation were favorable, a quarry might be opened here for the production of roofing slates.

The west slopes of the ridge consist largely of calc-schists, while on the east flank chlorite schists predominate. In places the latter are altered to talc-schists. Large masses of red jasper are also to be found, particularly in Sagay Creek. None of the numerous pans of river gravel which I washed during the traverse across the peninsula showed any colors.

I left the town of Jabonga in a small boat and, because of exigencies of the weather, had to put ashore two or three times, and was thereby enabled to determine the geologic formation of the west coast of Lake Mainit to be very similar to that of the ridge between the lake and the sea, that is, calcareous shale and chloritic schist.

The town of Mainit is situated on the north shore of Lake Mainit about 3.8 kilometers southwest of the mountain of the same name. I left the town in a small *banca*, going eastward along the shore of the lake as far as the mouth of the Magpayang River. About 3.5 kilometers northeast of here is a flat terrain enclosed between two creeks called Duyangan which are branches of the Tinagan River. About a generation ago this place had quite a reputation as a placer district, and several shallow pits about one-half to one meter deep are yet to be seen in the gravel, from which a Frenchman named Maximiliano and others are supposed to have taken a considerable quantity of gold. A pan of this gravel taken from the surface showed about a half dozen plainly visible colors and a small tail of flour gold. Whatever wealth this gravel might once have possessed, to-day it is not rich enough to attract even the native women with their *bateas*. A number of pans taken between the surface and hard pan, which lies about 1 meter below surface, yielded only at the rate of from 9 to 31 centavos per cubic meter. There were no signs of the hard pan having been penetrated, and what might be found below it remains problematical. Both the surface gravel and the underlying hard pan contain a considerable amount of chalcedonic quartz and concretions of brown clay-ironstone, as well as some black sand, pyrite, and gold.

A wide, open stretch of flat cultivated land is passed in going north from Tinagan. The geologic formation here was difficult to determine for lack of outcrops, but near the town of Timamana about 3.3 kilometers northeast of Mount Mainit are three or four hills, 20 to 30 meters high, and composed of crystalline limestone. These hills are plainly the uncovered portions of the underlying formation, standing out above the tuffaceous material derived probably from the ejecta of Mount Mainit in its active state and which at present cover the rest of the underlying formation.

The trail northward from Timamana passes almost on the contact

between limestone on the west and basalt and andesite on the east. The igneous rock has been largely disintegrated and the trail passes mostly over a red residual clay which shows traces of large, weathered feldspar phenocrysts of the andesite.

A small community of Filipinos lives in the *barrio* of Tinabingan on the west coast of the Bay of Placer. Tinabingan is known chiefly in the Province of Surigao for its former activity in gold washing. Old and abandoned tunnels, shafts, and ditches evidence the fact that this industry at one time must have engaged a great number of people. To-day, the only mining work done by the native population still remaining, consists in the washing of the black sands on the beach. One American miner lived at Tinabingan at the time of my visit there. Working absolutely alone, and with but small capital at his command, it is not at all surprising that this one man could show but a very limited amount of development, particularly so as he had been unfortunate in losing a large part of his work as a result of slides and caves.

The country rock of this region is andesite, intersected by a system of veins, running in general about north 55° east and dipping 60° to 70° toward the southeast. Many of these veins are mere quartz stringers less than one centimeter in thickness. In general, the walls of these stringers have become silicified to a greater or less extent, making the limits of the mineralization very indefinite.

About 7 kilometers northeast of Placer is the small island of Campiña, where at one time comparatively extensive mining work was carried on. The mouth of the main tunnel, about 5 meters wide and 10 meters long, is found on the southern end of the island about 60 meters from the beach. This tunnel is intersected by several short drifts, running in all directions and at all inclinations, and now generally caved and in a dangerous condition. The walls of the workings are mostly covered with a clay gouge and no distinct vein could be observed anywhere. It is possible that here, as in Tinabingan, the natives had discovered comparatively rich, but very narrow stringers of quartz and had followed them until the values had disappeared, or else the abandonment was caused by the flooding of the workings, for the floor of the main tunnel is only about 3 meters above sea level, and the lower workings were flooded at the time of my visit. Numerous samples were taken from what appeared to be the most probable pay streaks, but the assay results are so extremely low that the wonder is that even the natives could have found this mining profitable or sufficiently encouraging to have done as much work as they have.

An old placer district, that has been worked by Spaniards and Filipinos for a long, but an indefinite period of time, exists about 10 kilometers south of the town of Surigao, at the head of the Cansuran and Biga Creeks, both tributaries of the Surigao River. Many of the wealthier

families in and about the town of Surigao possess heirloom nuggets, some as large as a twenty-dollar gold piece, which were obtained in the Surigao gold fields in by-gone days. But few people at the present time are engaged in this business continuously, and these, working on a small scale and with the crudest facilities, make but little more than a living from their operations. Cansuran Creek, from its junction with the Biga to Mount Binutong where it rises, everywhere shows signs of old workings in the form of excavations, ditches, and ground sluices. Great quantities of large boulders, generally chloritized or serpentinized, and smaller ones consisting almost entirely of quartz, are to be found in the bed of Cansuran Creek. The banks of the stream are for the greater part slate, striking approximately north 66 west and dipping at varying angles but usually toward the northeast. Going toward the south or head of the creek, the slate becomes more and more altered by chloritization and folding, with the development of prominent and important cleavage planes.

The benches that are worked are as a rule situated 10 to 30 meters above the creek, and the gravel, which appears to be the result of surface disintegration and erosion of the country rock, consists mostly of chloritic schist, this being also the base rock of the ground sluices.

Numerous igneous boulders are to be found in the gravel and the origin of these is accredited to Mount Canmahat, a prominent conical hill arising from the valley of the Surigao River near the head of Cansuran Creek, to an elevation of about 180 meters above the creek. This hill has all the appearance of a small extinct volcanic cone; the summit and upper slope are composed entirely of andesite, but about 100 meters below the summit the underlying shale appears. Curiously enough, the upper courses of the underlying shale both at Canmahat and the neighboring hill Binutong, are less chloritized and otherwise altered than the deeper seated shale. Gravel washing begins at a depth of 40 to 50 meters below the contact of the shale and andesite. The igneous boulders are usually more numerous than those of the schistose variety, and generally lie above them, the latter evidently being more nearly in place.

Gold can be panned from the surface down, but the colors obtained from the top gravel are extremely fine and mostly lost by the methods of mining in vogue. Most of the gold comes from the lower course, not only because of the concentration which would naturally take place on bed rock, but also, I think, because the gold is derived from the very fine quartz and calcite stringers which so thoroughly but irregularly intersect the bed rock of chloritic schist. Two varieties of gold are obtained on Cansuran Creek, in varying proportions depending upon the location. The one is the ordinary, rounded and smoothly worn grain, while the other, somewhat lighter in color, is very markedly crystalline and with sharp edges, and frequently contains inclusions of both calcite

and quartz. The latter undoubtedly comes from the disintegration of the bed rock at or nearly in place, and the subsequent crushing of the fine intersecting stringers of calcite and quartz.

In four days of mining and one day spent in cleaning up the sluice, a native miner assisted by his wife and two male helpers, washed approximately 7.5 cubic meters of gravel, cleaning up therefrom 260 grams of gold for which they were paid 15.60 pesos,²⁰ equivalent to about 2.08 pesos per cubic meter. This was considered as an average run and will give an idea of the richness of the gravel and what might be accomplished if mining were undertaken on a large scale and with such modern hydraulic methods as are practiced in California.

The smaller tributary creeks contain no water except during the rainy season, but the larger creeks such as the Cansuran, the Bigaa and the Tagunaan (or Caningan) are fairly large water courses and probably never run absolutely dry. The last two, by the way, showed about as good results in panning as did the first, yet very little mining is done at present on any except Cansuran Creek.

²⁰ One peso is equivalent to 50 cents United States currency.

ILLUSTRATIONS.

PLATE I.

The slopes of one of the worn down volcanic stocks on Jolo Island. (Photograph by Smith.)

PLATE II.

Flow lines in andesite at the summit of Mount Apo. (Photograph by Smith.)

PLATE III.

FIGS. 1 and 2. Various stages in the eruption of Camiguin Volcano, May, 1871.

PLATE IV.

FIGS. 1 and 2. The eruption of Camiguin Volcano, May, 1871.

PLATE V.

FIGS. 1 and 2. Metamorphism in a specimen of coal from Dumanquilas Bay, Mindanao. (Photographs by Martin.)

MAP.

Geologic map of Mindanao.

TEXT FIGURE.

Probable outline of Mindanao in Tertiary times.

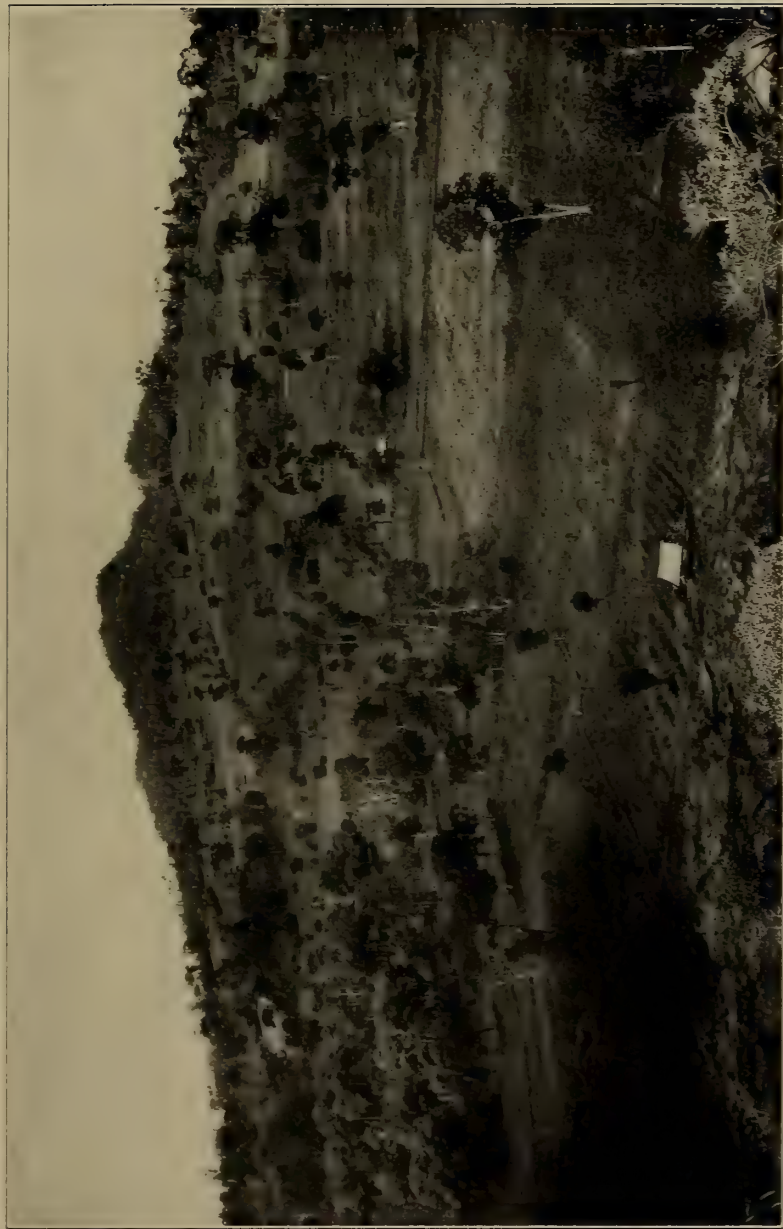


PLATE I.



PLATE II.



FIG. 1.



FIG. 2.

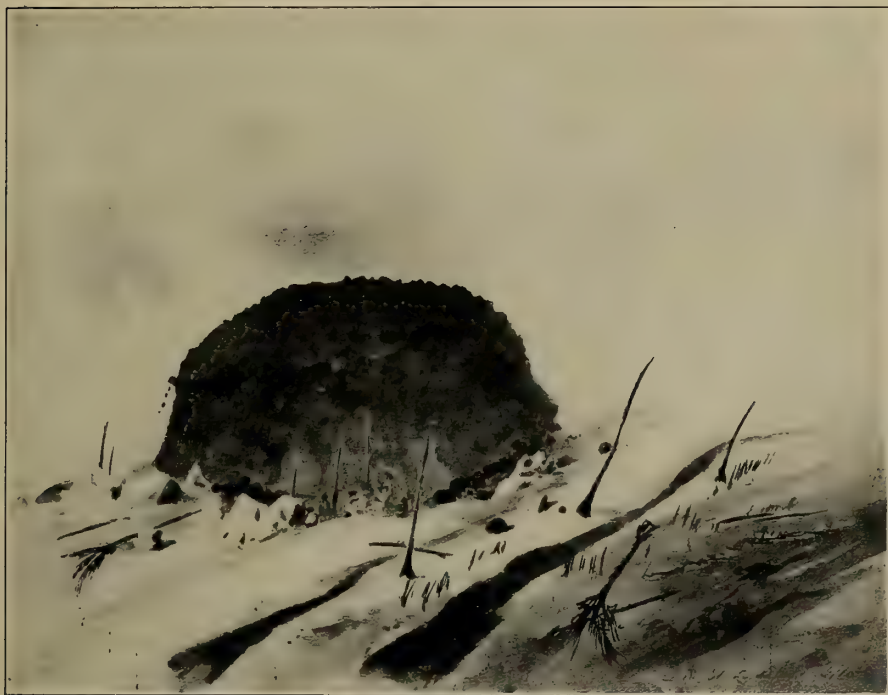


FIG. 1.



FIG 2.

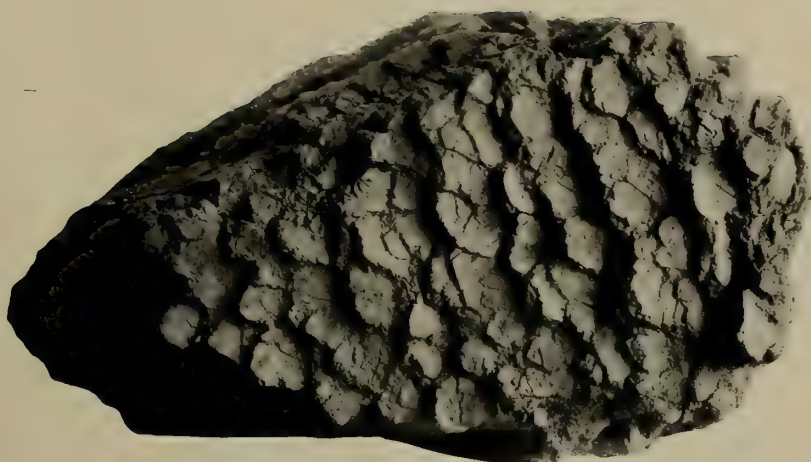


FIG. 1.

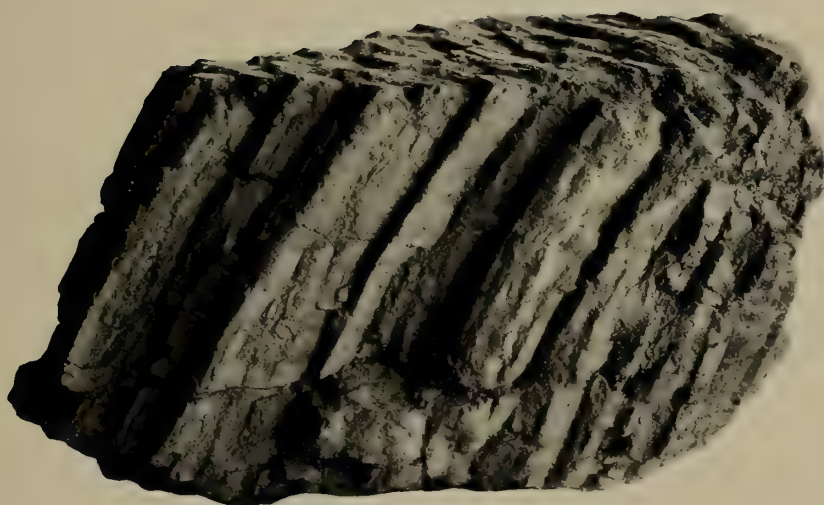


FIG. 2.

PLATE V.

THE GEOLOGY AND MINERAL RESOURCES OF THE AROROI DISTRICT, MASBATE.

By HENRY G. FERGUSON.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

CONTENTS.

INTRODUCTION.	The basic rocks.
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THE ISLAND OF MASBATE.	The Port Barrera formation.
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Topography.	ECONOMIC GEOLOGY.
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The andesite.	Timber.
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The sediments.	Labor.

INTRODUCTION.

Field work.—During the winter of 1907–1908 I was engaged in geologic and topographic field work in the Aroroi mining district on the Island of Masbate. Although the greater part of this time was spent in topographic mapping (See Plate I), a portion was devoted to a preliminary study of the geology, and a short reconnaissance made over a portion of western Masbate. In the spring of 1909 I made a two weeks' visit to the island for the purpose of collecting mining statistics. However, the major portion of the geologic work was done in the autumn of 1909. During the greatest part of the topographic work the writer was assisted by Mr. R. N. Clark, field assistant of the division of mines. Thanks are due to all the mining men of the region, especially Messrs. Berkenkotter, Herbert, Kimball, and Edelmaier, for their unfailing hospitality and courtesy, and for much valuable assistance.

Bibliography.—It was not until after the rediscovery of gold at Aroroi

in 1901 that the island was visited by geologists. However, the earlier writers had noticed the significant form of the island in relation to the principal structural lines of the Philippines. Von Drasche¹ first called attention to this junction of the two principal trends of the Visayan Islands. Koto² suggested a similarity to the divergence of the mountain system of the Eastern Alps. Suess³ noted a possibility of similarity of structure to that of Porto Rico. Becker⁴ speaks of two main, curved fissure-systems parallel to the two arms of Masbate.

Mr. A. J. Eveland, at that time geologist in the Mining Bureau, made a short visit to Aroroy in 1904 and noted in his report⁵ the topographic youth of the district and the limestone benches on the west side of Port Barrera. Mr. H. D. McCaskey and Mr. H. M. Ickis made a more extended visit in 1906. Mr. McCaskey in his report⁶ was the first to call attention to the fact that the great majority of the mineral veins strike in a northwesterly direction, parallel to the principal axis of the island.

The writer published in 1908 a short résumé of the mining conditions and geology of the Aroroy district,⁷ and the results of the first season's field work were made the basis of a more extensive paper on the physiography of western Masbate.⁸

Notes on the mining developments of the year are published in the annual bulletin, *The Mineral Resources of the Philippine Islands* for 1908.⁹ A more detailed statement of the economic geology and mining occur in the same bulletin for 1909.¹⁰

THE ISLAND OF MASBATE.

Climate.—The rainfall on Masbate is well below the average for the Philippines (2,200 millimeters); observations at Port Palanog (Masbate) for the years 1904, 1905, and 1906 give an average annual rainfall of only 1,446 millimeters. The records show a smaller rainfall at only four out of the sixty-four stations in the Islands. The dry season extends from February to May, inclusive, only 17 per cent of the total precipitation occurring during these four months. Throughout the remainder of

¹ *Fragmente zu einer Geologie der Insel Luzon.* Vienna (1878).

² On the geologic structure of the Malayan Archipelago. *Journ. Coll. Sci., Tokyo* (1899), II, 11, 117.

³ *The face of the earth* (English translation). Oxford (1906), 2, 173.

⁴ Report on the geology of the Philippine Islands. *21st Ann. Rep. U. S. Geol. Surv.* (1901), 546.

⁵ Manuscript in Bureau of Science, Manila.

⁶ Manuscript in Bureau of Science.

⁷ *Far East. Rev.* (1908), 5, 56.

⁸ *This Journal, Sec. A* (1909), 4, 1-16.

⁹ Ferguson, H. G., *Metallic Mineral Resources. Min. Resources P. I. Bur. Sci., Div. Min.* (1909), 20-21.

¹⁰ *Ibid* (1910), 18-25.

the year, the rainfall is distributed fairly evenly. Destructive typhoons visited the island in November, 1905, September, 1908, and December, 1908.

While there are no figures available for the precipitation in the Aroroi district, I believed that it is undoubtedly less than at the town of Masbate itself, as abacá (Manila hemp) can not profitably be grown at Aroroi, while a small amount is produced in the vicinity of Masbate and also farther southeast toward Kataingan. Even in the Aroroi district itself the rainfall is uneven, the majority of the showers during the rainy season passing through the southern part of the area to the south of Mount Kalakbao. The temperature records for the year 1909¹¹ are given below, and show a very even temperature with a smaller range between the seasons than at Manila.

Mean temperature for the year 1909 by months.

Month.	Mean temperature, °C.	
	Palanog, ^a Masbate.	Manila.
January	26.3	24.7
February	27.0	25.3
March	27.8	26.1
April	29.3	28.2
May	29.6	28.2
June	29.5	27.8
July	27.7	26.1
August	29.8	27.4
September	28.1	26.3
October	28.1	26.9
November	27.3	25.8
December	26.1	24.2
Annual	28.0	26.4

^a No weather station at Masbate, hence record taken from Palanog, the nearest station.

Population.—The population of the island is given in the census of 1903 as 29,451, or about seven to the square kilometer. This is small compared with other islands of the Visayan group, and Masbate could easily support a much larger population. The people are for the greater part Visayans, and the language spoken is a dialect of Visayan. There is a scattering of Bicolans and Tagalogs, especially along the northern coast. The people are peaceable, hospitable, and friendly, and although of course irresponsible and not very energetic, they make as good workers as are to be found elsewhere in the islands.

Topography.—The Island of Masbate lies almost exactly in the center of the Philippine Archipelago, between latitudes 11° 43' north and 12°

¹¹ *Month. Bull. P. I. Weather Bur.* (1909).

36' north, and longitudes 123° 09' east and 124° 05' east, and has an area of approximately 4,000 square kilometers. It owes its unique, two-pronged shape to the junction of the two prevailing anticlinal trends of the Visayan Islands and central Luzon. To the inner series, as described by Becker,¹² belongs the western arm of Masbate, which is continued in eastern Panay, Guimaras, and the Cagayanes, and is parallel to the curves formed by Palawan and the Culion group to the west, and the Negros, Zamboanga Peninsula, and Sulu line to the east. The trend of the larger arm of the island is continued through Leyte and eastern Mindanao and is parallel to the outer line formed by Samar and southern Luzon.

Masbate is mountainous and the greater part of the interior is unexplored. A fairly continuous range of hills rises steeply from a narrow plain on the western prong. The maximum elevation of this range is about 600 meters at Mount Gantal. The larger arm of the island is not a continuous range but is broken by two transverse valleys: one between Milagros and Port Palanog, and the other southerly from Uson. Except for these two troughs, the country is extremely rugged and mountainous. The highest mountain of the island, Mount Simbahan, lies 11 kilometers south of the village of Baleno and 18 kilometers southeast of Aroroy, and has an elevation of 660 meters. Two high peaks, Capuluhan and Bagulipat, occur in the mountainous country southeast of the Milagros-Masbate trough. A peculiar feature of the topography of this part of the island is the course of the Malbug River, which rises near the northeastern coast and flows southeast parallel to the coast, until near Uson it makes a sharp turn at right angles to its former direction and flows southwest into the Gulf of Asid. The largest rivers of the island, the Asid and Malbug, drain into the shallow Gulf of Asid. The crests of the mountain ranges lie near the northern shore, there being a considerable stretch of plain and piedmont country on the southwestern side of the main prong of the island. Similarly, the greatest depths near the shore are to be found along the northern and northeastern coast, especially between Naro Bay and Point Bugui, where there is a depth of 911 meters at a point less than 3 kilometers north of Bagubau Point, while off the southern coast shoal water extends for a great distance. On the accompanying map the submarine contours of 50, 100, and 200 meters depth are shown. The excellent harbors of Port Barrera (Aroroy), Port Palanog (Masbate), Naro Bay (Dimas Alang), and Port Kataingan are situated on the northern and eastern coasts. On the west coast the only harbor is Port Mandaon. The Gulf of Asid, on the south coast, is so shallow that only small boats can call at Milagros.

Geology.—The two cordillera ranges are in part composed of older

¹² Report on the Geology of the Philippine Islands, *21st Ann. Rep., U. S. Geol. Surv.* (1901), 546.

sediments, largely slates, intruded throughout large areas by diorites and more basic plutonic rocks, and associated with a large amount of later volcanic rocks, of a rather basic type, ranging from rare dacite, through andesite to basalt and leucitite, with accompanying pyroclastics. No fossils are found in the early sediments, but from the great discordance between them and the unmetamorphosed Miocene sediments, I believe that it is not unreasonable to class them provisionally as pre-Tertiary. Scattered outcrops of a dark blue limestone are to be found along the shores of Asid Gulf and inland on the flanks of the mountain range. This occurs as a capping unconformably above the older formations. Dr. W. D. Smith has found the characteristic fossil *Lithothamnium ramossissimum* Reuss in thin sections of this rock, and considers the formation to be of Middle Miocene age.

An extensive sedimentary formation of Miocene age, containing coal, occurs between Punta del Este at Port Kataingan and Naro Bay. This series rests upon a base of schistose quartz diorite and is composed of a basal arkose followed by a sedimentary series containing several coal seams which are overlaid by another slightly unconformable sedimentary series. Between Kataingan and Dimas Alang where the writer has had an opportunity to make a reconnaissance of the coal measures, the sedimentary series is found to be bent into a very sharp syncline, the axis of which follows the prevailing northwesterly trend. These sediments in all probability continue northwestward on the unexplored Island of Ticao.

On the northwest corner of Masbate, a similar formation consisting of shales, limestone, and a large development of conglomerate, but so far as now known without coal, extends southwestward from the western part of Port Barrera to Point Mariveles on Nin Bay. There are occasional outliers from these sediments to be found farther inland, but the main boundary shows in a well marked escarpment of limestone and conglomerate. The dip is quite gentle and generally to the northwest, and the submarine contours along the west coast of the island suggest the continuation of the formation for some distance seaward.

Limestones and conglomerates, evidently of quite recent date, occur at several places along the northeast coast, such as Points Vigia (Vihia), Marintok, Bagubau, Kapandan, and Colorada.

Earthquakes.—The Atlas de Filipinas divides the island between “rather frequent” and “rare” earthquake areas, the “rather frequent” zone lying, as would be expected, along the very deep Ticao strait between Masbate and Point Bugui. In a recent catalogue of destructive earthquakes,¹³ six earthquakes above VI of the Rossi-Forel scale are stated to have been felt in the years 1869, 1874, 1893, (two) 1897, 1900.

¹³ Catalogue of Violent and Destructive Earthquakes in the Philippines. Weather Bur. Manila, P. I. (1910).

THE AROROI DISTRICT.

LOCATION AND TOPOGRAPHY.

The Aroroi mining district is situated near the northwestern corner of the island in the group of hills to the east of Port Barrera, which is a deep bay extending southward for a distance of about 13 kilometers. Anyone entering this bay must be struck by the extremely different topography exhibited on either side. To the westward are series of nearly horizontal sedimentaries, limestone, conglomerate, and shale. The limestone outcrops form a regular series of terraces which can be followed without a break for great distances. Toward the southern part of the bay erosion has broken these terraces into a number of small mesas. On the other hand, the country on the Aroroi side is more irregular and the hills present smooth, rounded outlines without any trace of terracing.

Mount Vil-lon, lying just outside the area mapped, is the highest mountain in the district, having an elevation of about 400 meters. It differs from the other hills in having a northeasterly trend, and breaks off precipitously at Monument Rock, near the Guinobatan River. The majority of the mineral veins outcropping in the district are found in the three hills, Mounts Aroroi, Bagadilla, and Kalakbao. While the summits of these three hills lie in a north and south line, the individuals show a pronounced northwesterly trend, due to the superior resistance to erosion offered by the quartz veins. Mount Aroroi, or Kanatanatawan, (elevation 255 meters) lies farthest to the north and is separated from the highest of the three hills, Mount Bagadilla (elevation 350 meters), by Bangon Creek, which here flows through a deep cañon. Mount Bagadilla, on its western side, sends out several northwesterly spurs marking the situation of different quartz veins. The gorge of the Guinobatan River separates Mount Bagadilla from the southern hill, Mount Kalakbao, which has an elevation of 220 meters.

A long stretch of irregular country broken by a series of small hills extends to the south and west from Mount Kalakbao until the Lanang River is reached. (Plate I, fig. 2.) This river cuts a complicated channel through a range of hills of over 200 meters elevation, and follows a northwesterly course. Mount Cogran lies just to the northeast of this range, its height being due to the resistance of the quartz veins which outcrop here.

The area is drained by several permanent streams, all of which (the Buyuan River lying outside the area proper) drain northwestward into Port Barrera. Three principal streams drain the area: The Guinobatan River, Panique Creek, and the Lanang River. The northern branch of the Guinobatan, Bangon Creek, flows in a deep gorge between Mount Aroroi and Mount Bagadilla; while its direction is northwesterly it does not follow the strike of the quartz veins, but cuts obliquely across

them and joins the Guinobatan about one kilometer from its mouth. The Guinobatan rises near Mount Baha Simbahan and flows in a general northeasterly and northerly direction, partly encircling Mount Vil-lon. Its course between Mounts Kalakbao and Bagadilla is almost westerly; like the Bangon, it cuts obliquely across the vein system. Beyond the gorge the stream turns sharply to the north and for two kilometers flows parallel to the bay and about one kilometer distant from it. Panique Creek drains the greater part of the irregular area lying between Mount Kalakbao and the Lanang Range. The peculiarities of the course of the Lanang River have been discussed at length in my paper on the physiography of western Masbate.¹⁴ It, like the Guinobatan, rises on Mount Baha Simbahan, and where mapped in the Aroroy district presents a very peculiar course which seems to be the result of successive stream captures, for instead of flowing down the broad valley to the north of the Lanang range, which apparently was its earlier course, it twice cuts through the range in deep gorges. The Luya, a tributary of the Lanang, flows from the northern side of Mount Cogran and joins the main stream about two kilometers above the upper gorge.

The southern shores of Port Barrera are lined with mangrove swamps, which have a very large development at the mouth of Lanang River, and at the head of the bay near the *barrio* of San Agustin.

GEOLOGY.

In the geologic map accompanying this paper, the rocks are divided into six formations as follows:

1. The *Kaal formation*, containing the oldest rocks in the district, chiefly slates, outcropping in the valley of Kaal Creek and in isolated patches to the northward.

2. The *Aroroy quartz diorite*, occupying the northern portion of the area and intrusive into the Kaal series. With this are mapped scattered outcrops of other deep-seated igneous rocks including diorite, gabbro, and syenite.

3. The *Panique volcanic series* which covers the greater part of the area. On the map this series has been subdivided roughly into the dominant andesitic types, the pyroclastic rocks, and local areas of sediments derived from the andesite and the more basic igneous rocks.

4. The *Mountain Maid limestone*, the single outcrop in this district of the blue limestone already referred to, is found on the Mountain Maid claim in the Guinobatan Valley.

5. The *Lanang formation* of conglomerate and sandstone forming the hills to the south of the Lanang River.

6. The *Port Barrera formation*, consisting of Miocene sediments, found only on the opposite side of Port Barrera.

¹⁴ *Loc. cit.*

The Kaal formation.—This series of sedimentary rocks outcrops in an irregular band in the western part of the area, running north from the western flank of Mount Vil-lon for about 6 kilometers to a point east of Mount Aroroy, and occurs farther north in irregular areas near the Aroroy quartz diorite formation. These sediments everywhere are the least resistant of the rocks found in the area, and hence are encountered only in comparatively rare outcrops, for the most part in the stream beds. Between Kaal Creek and Mount Vil-lon there is a small plain at about 50 meters elevation, where boulders of psilomelane are found on the surface. Prospecting has shown that the rock here is a very fine-grained, firm, red slate, without traces of banding, containing psilomelane in lenses parallel to the slaty cleavage. A similar red slate with manganese is found farther north, east of the junction of Balangting Creek with the Guinobatan River, and also, on the opposite side of the Guinobatan above the gorge, but here without the manganese. Several outcrops of a dark slate are found in Kaal Creek itself and its two small tributaries. As a rule, this is faintly banded, showing poorly marked narrow bands of dark and slightly lighter material. The strikes and dips are constantly changing, suggesting great contortion, but as a general rule, where bedding is observable in the rocks of this formation, the strike is northeasterly, and the dips, although extremely variable, are for the greater part steep to the northwest. This darker slate almost invariably is lined with a minute network of quartz and calcite veins, generally not over one centimeter in width and grading down to microscopic veinlets. Much of the slate found in irregular areas on Lubigan and Ambulong Creeks is similar to this. Another phase found in the same localities is a fine-grained, dark purple slate, very similar, except in color, to the red slates east of Kaal Creek. The outcrop of the Kaal formation on the coast, west of the village of Aroroy, and other outcrops east of Mount Aroroy show a graywacke rather than a slate. In the latter locality a grit or coarse-grained sandstone occurs, the pebbles of which, where large enough to be seen, all seem distorted; as far as could be discovered they are composed entirely of sedimentary rock, apparently a fine-grained, dark slate. No pebbles of igneous rock were found anywhere, nor did there appear to be any phase of this formation which might be interpreted as the basal conglomerate of the series. The most interesting outcrop of this formation occurs on the point forming the western corner of Buyuan Bay; here a dark slate, similar to that found in Kaal Creek is seen to be intruded by a small stringer of quartz diorite. Not far from this the slate appears to be in contact with a larger mass of diorite, although the evidence of intrusion is not so clear as in the previous case.

In the vicinity of Lubigan and Ambulong Creeks the slate is frequently cut by dikes of the fine-grained igneous rocks which have been grouped together in the Panique formation. The slate is clearly older than the

latter, and it is reasonable to conclude that the Kaal is the oldest formation here exposed. Of course, the intrusion by the diorite of a slate similar to that of the main sedimentary mass is not of itself absolute proof, but were the slate not older than the diorite it would be strange if somewhere a basal conglomerate containing diorite pebbles, were not found. Little can be said as to the absolute age of the Kaal formation. No fossils have been found, but judging from its position, its extreme contortion and considerable metamorphism, it is my belief that it may be classed provisionally as pre-Tertiary,¹⁵ the earliest Miocene shales of the Port Barrera formation.

The Aroroy quartz diorite.—The quartz diorite mass mapped under this name is of comparatively limited extent in the Aroroy district, being found only in the extreme northern part of the area. However, it widens extensively to the eastward, being the principal rock met with between the Guinobatan River and Magdalena Bay.

The details of the petrography of the igneous rocks of this series and the more varied types to be found among the volcanics of the Panique formation are left for a future paper, the present article being more particularly concerned with the economic geology. Dr. Iddings,¹⁶ in a preliminary article on Philippine petrography, has described several of the characteristic rocks from this district. It will be sufficient to mention that the quartz diorite is generally rather fine grained, with granitic texture, although coarse grained phases are common. The visible minerals are feldspar and hornblende; rarely biotite. Under the microscope the feldspars prove to be andesine and oligoclase with rarely small grains of what apparently is orthoclase; the area pertaining to this mineral is about 60 per cent of the slide. Quartz occurs in the interstices between the feldspars. The quartz grains are often cracked and show cloudy extinction due to strain. This mineral occupies rather more than 20 per cent of the area of the slide, and the hornblende rather less than this. Magnetite occurs in scattered, minute grains. The striking feature of the rock is the small proportion of femic minerals which in general are present.

Scattered outcrops of deep-seated igneous rocks occur, along the Guinobatan River and near the headwaters of Balangting Creek. These rocks, for convenience, are mapped with the quartz diorite; under the microscope they are found to include diorite, syenite, and gabbro. Nothing definite could be learned in regard to their field relations. No contacts were found between the quartz diorite and the apparently overlying volcanics of the Panique group, but from the position of the latter it is

¹⁵ Metamorphism is no longer considered an indication of age; Tertiary rocks have been subjected to profound dynamic stresses and are metamorphosed. Without fossils the question can not be satisfactorily settled. W. D. S.

¹⁶ *This Journal, Sec. A* (1910), 5, 155.

not difficult to decide that they are of much later date than the former, and it seems probable that the quartz diorite had undergone considerable erosion before the eruption of the Panique series.

The Panique series.—Volcanic rocks and their pyroclastic derivatives cover by far the larger portion of the Aroroy district (Plate II, fig. 1) and as they show great petrographic variety this formation might be split into a far greater number of units. The different outcrops are so scattered, and their limits so uncertain, that it would be exceedingly difficult to show all the rock types on a map of this scale without confusion. The following igneous rocks, included in this formation, have been determined microscopically: Dacite, augite-andesite of several varieties, hornblende-andesite of at least three distinct types, several types of basalt, and leucite tephrite. The formation is divided on the map as follows: The andesites, which are the common rocks of the district, the pyroclastic rocks, including agglomerates and tuffs, the rather rare occurrences of sedimentary rocks derived from the andesites, and the more basic rocks. In working on the igneous rocks of the area it has been found difficult to show fine distinctions, as they are so deeply decomposed in places as to make determination difficult, and in many cases a certain amount of transportation has been added to this decomposition, forming arkose-like rocks, the "toba" of the Spanish geologists.

The andesites.—Augite andesite is the commonest volcanic rock here as elsewhere in the Philippines. The rocks of this type have been described so often that a repetition seems unnecessary. Moreover, notes on the augite andesite from Aroroy will be found in Idding's paper.¹⁷ The rocks of this type found here are, as a general rule, markedly porphyritic and show prominent phenocrysts of augite and feldspar, the former being the most prominent. A peculiar phase of the augite andesite is exhibited on the shore of Port Barrera near Maguilanguilan Island, where the rock is extremely porphyritic and carries phenocrysts of augite, the bases of which are sometimes as much as 15 millimeters square. The feldspar phenocrysts grade from andesite to labradorite, and are of smaller size than the augites. Magnetite is present in varying amounts. The ground-mass always shows the characteristic hyalopilitic texture with occasional marked flow-structure. While the presence of large amounts of pyroclastic rocks derived from the augite andesite is evidence that a part at least of this series is of extrusive origin, in only one place was any structure found indicative of a surface flow. At one point in the western part of the district the andesite was found to contain broken blocks of the same rock, as if it had been brecciated at the bottom of a surface flow. The lack of large exposures greatly reduced the chances of finding other similar evidence. With the appearance of olivine, the augite

¹⁷ *Loc. cit.*, 157.

andesite passes over into a basalt, while on the other hand the appearance of hornblende in place of the augite gives the hornblende andesite.

The hornblende andesites are mapped with the augite andesites and it is often difficult to distinguish between the two in the decomposed rocks frequently met with here, owing to the decomposition of the femic minerals. The largest areas of hornblende andesite are in the range of high hills just north of the Lanang River, and in Mount Vil-lon. Specimens from the former show small hornblende phenocrysts and rather more acid feldspar than is found in the augite andesites, and a slightly larger proportion of salic minerals. Quartz is present occasionally. In another part of the area enough quartz is found under the microscope to bring the rock into the rank of dacite. The Mount Vil-lon andesite contains similar minerals, but is much more porphyritic, the phenocrysts so far exceeding the ground-mass as to make it doubtful whether the rock should not be classed as a diorite porphyry. A very peculiar type of hornblende andesite is that occurring in occasional outcrops, probably dikes, in the two creeks north of Mount Aroroi. Here the rock is characterized by an extremely fine-grained hyalopilitic ground-mass containing minute rods of andesine feldspar, small andesine phenocrysts, scarcely noticeable hornblende phenocrysts often reaching a length of 3 or 4 centimeters.

The pyroclastic rocks.—As will be seen from the map, the pyroclastic rocks cover the greater part of the central portion of the area. The greater proportion of these rocks are agglomerates, always derived from augite andesite, suggesting that the period of extrusion was contemporaneous with the augite andesite phase of the volcanic series. The agglomerate contains large, angular blocks of augite andesite often exceeding half a meter in width. On the outcrop, the weathering proceeds most rapidly in the matrix, giving the rock an irregular appearance which makes it easily recognizable. Small beds of andesitic tuff and volcanic ash occur with the agglomerate, but these are comparatively unimportant; in general it may be said that the whole are mapped as pyroclastic and may be considered as covered by agglomerate. Where contacts between the different beds are found, as for instance on Balawing Point, the strike is northwest and the dip rather gentle to the southwest.

The sediments.—Waterlaid sediments derived from the augite andesite are found in two localities, on Panique Creek and on the Gold Bug claim, at the mouth of the gorge of the Guinobatan. There are alternations in Panique Creek of a rather fine-grained feldspathic sandstone, containing in its coarser phases small pebbles of augite andesite and thin beds of fine volcanic ash with fragments of augite crystals, separated by layers of carbonaceous material, these never exceeding 3 or 4 millimeters in thickness. The sediments here suggest temporary lacustrine conditions. The strike is northwest and the dip 10° to 20° to the southwest. On the Gold Bug claim the lower member of the series is a black shale heavily

pyritized, exposed in the bottom of the open cut, back of the Gold Bug mill. Although none of the original minerals are visible to the eye, the microscope shows a large number of broken plagioclase grains, together with rarer augite grains and innumerable specks of black material, probably carbonaceous matter. This shale again suggests local lacustrine conditions. Above the shale are coarse and irregular conglomerates and sandstones, with irregular and angular pebbles and grains, probably resulting from torrential deposition. The pebbles of the conglomerate, although much decomposed, appear to be derived from the augite andesite. These rocks are cut by a basic dike and small quartz veins. The accompanying mineralization will be discussed when the economic geology of the district is considered.

The basic rocks.—The basic rocks are for the greater part basalts, differing from one another and from the augite andesite in the relative proportions of olivine, the greater basicity of the feldspars present and the relative preponderance of the femic minerals. From their scattered distribution it is probable that they occur in dikes cutting the andesites and earlier rocks.

One peculiar type merits more detailed description. This rock, a leucite tephrite, is found in a single outcrop just to the west of the road and about one kilometer due west of the summit of Mount Aroroy. In the hand specimen it is a black, fine-grained porphyritic rock, the most prominent phenocrysts being dark augites generally two or three millimeters in length, and occurring in great numbers. Large grains of olivine may sometimes be seen, but this mineral is rare. Very minute, glassy leucites can be detected with the hand lens. Under the microscope the augite shows large, fresh, faintly pleochroic crystals with sharp boundaries, often twinned on 110. It frequently contains inclusions of magnetite grains and the larger magnetites are generally associated with it. In one case a large augite crystal seems broken up into a great number of small grains, and small crystals also are scattered through the ground-mass, the smaller grains showing the most marked pleochroism. The augites, particularly the larger individuals, have clusters of minute, black needles radiating from their sides, most numerous near the corners. In all, the augite phenocrysts cover about 30 per cent of the area of the slide. Feldspar is present in small amounts, but is so decomposed as barely to be recognizable. From its low index of refraction it is inferred to be orthoclase. Next to augite, leucite is the most prominent mineral. It occurs in groups of not more than a dozen crystals in each, the single individuals seldom measuring over 0.35 millimeters in diameter. As a rule, the crystals are fairly clear, but the larger ones often contain small black specks as well as minute grains of augite and small, transparent rods. The smaller crystals are entirely dark between the crossed nicols, but the larger ones show very faint lines of anomalous double refraction.

The magnetite is not very prominent, although several large grains occur. It is generally, though not always, associated with the augite.

The ground-mass is largely made up of indistinguishable alteration products, probably resulting both from the decomposition of the feldspar and the devitrification of the glassy base. However, in parts of the slides there seems to be a dark, greenish glass containing minute black rods. These rods are extremely fine and narrow, and, although occurring in greater numbers around the edges of the augite and less prominently about the leucite phenocrysts, form an irregular, branching network throughout the ground-mass. Possibly these are skeleton crystals of magnetite.

The occurrence of this potash rock among the andesites and basalts of this district is most unusual, and all the more so as it is the only leucite-bearing rock known in the Philippines or Japan. Behrens¹⁸ has described similar rocks from Java.

The outcrops in the vicinity of the leucite tephrite are all of andesite agglomerate and it seems probable that the rock occurs as a dike cutting the agglomerate. This is all the more likely as the dike already described as cutting the sediments on the Gold Bug claim seems to be of similar type, though much decomposed and without recognizable leucite.

While the evidence is too doubtful to make advisable any definite statement, the sequence in the Panique series seems to have been as follows: The hornblende andesite probably is the earliest and the mass of Mount Vil-lon is intrusive, although it is uncertain whether the rock forming the hills north of the Lanang River is intrusive or effusive. The larger hills between Kalakbao Hill and Panique Creek and including Panique Hill are augite andesite and may represent the stocks of the volcanoes from which issued the mass of pyroclastic material which to-day covers such a large part of the area. Periods of quiescence during the volcanic activity are marked by the sediments found in Panique Creek and on the Gold Bug claim. The basalts found in various parts of the area probably are later than the andesite, and the youngest rocks of the series are almost certainly the leucite tephrite and the related dike, cutting the Gold Bug sediments.

The Mountain Maid limestone.—On a small southerly spur of Mount Bagadilla, just at the eastern end of the gorge of the Guinobatan River, at an elevation of about 150 meters, is a small outcrop of a dark blue limestone, similar to that found in places along the main range of the island. Dr. Warren D. Smith, who has examined thin sections of this rock, considers it to be of Middle Miocene age. Thick jungle surrounds the outcrop, and the field relations consequently are uncertain.

¹⁸ Beitrage zur Petrographie des indischen Archipels. *Natuur. Verh. d. Koninkl. Akad. Leiden* (1880), 23, 38, 58.

It apparently extends north and south for something over 100 meters, has a width of about 50 meters and a thickness of probably 20 meters, apparently resting on andesite. On its northern boundary it seems to be cut off by a small and barren quartz vein having a strike of approximately north 80° east. The only explanation which can be offered to account for the presence of the limestone here is that it is a remnant of a larger mass which once formed a capping over a great part of the region, and owes its peculiar topographic position to faulting. This explanation is unsatisfactory, for if this were the case we should expect to find either remnants of the capping at higher levels or outcrops of the same rock in the sediments of the Miocene formations on the opposite side of Port Barrera. Perhaps when the geology of the main southeastern range is studied more in detail, a better knowledge of the relations of this limestone to the other formations may throw some light on its occurrence at this point.

Since the more recent sedimentary rocks mapped as the Lanang and Port Barrera formations do not outcrop in the mining district proper, a short description will suffice. Both belong to the Miocene coastal plain, which rests upon the old land surface of the Aroroy district.

The Lanang formation.—A rather coarse conglomerate, composed largely of basalt pebbles, occurs south of the junction of the Lanang River and Kabakalan Creek and in the hill forming the center of the curious abandoned meander of the Lalang River. The conglomerate is evidently the basalt member of this sedimentary series, the pebbles being derived either from an undiscovered basalt outcrop on the hills to the northward, or a basalt flow formerly capping the andesite, and now removed by erosion. Above this, in the hills between the abandoned meander and the mass of andesite forming the lower gorge of the Lanang, conglomerate and sandstone occur, the former containing pebbles of andesite and dipping about 20° to the southwest. This basal series in all probability curves around the andesite mass at the lower gorge, but its continuation was not followed.

The Port Barrera formation.—On the northern shore of the westward embayment of Port Barrera (not shown on the large map) are outcrops of a fine-grained, gray shale containing numerous small shells of Lower Miocene age, irregularly interlaced with small sandstone dikes. This formation does not outcrop higher than about 4 meters above the level of high tide, and seems to dip very gently somewhat south of west. Doctor Smith considers this shale to be similar to that found above the coal measures in Cebú and Batan, and, in the hope of finding similar local seams, the shale was here prospected by drilling to a depth of 50 meters, but only shale was encountered. This evidence, together with that furnished by the topography of the country, makes it clear that Port Barrera originally was a river valley eroded in the soft shales

and drowned in a recent depression. Hence it seems probable that the low land lying south of the head of this bay represents the lower portion of the shale, and it is here that the coal measure should be looked for. Above the shale is an unconformity marked by 8 or 10 meters of conglomerate which here contains pebbles of augite andesite and vein quartz, evidently derived from the Aroroi district and hence an important factor in determining the age of the veins. Above the conglomerate are several beds of limestone belonging to the Upper Miocene or perhaps Pliocene. Doctor Smith has furnished the following notes relative to the fossils collected in these sedimentaries:

Mr. Ferguson and I visited this locality in August, 1909, and, collected a suite of fossils containing:

<i>Pleurotoma gendinganensis</i> Mart.	<i>Ranella spinosa</i> Lam., living.
<i>Pleurotoma carinata</i> Gray var. <i>woodwardi</i> Mart.	<i>Ranella nobilis</i> Reeve, living.
<i>Conus sulcatus</i> Reeve, living.	<i>Phos acuminatus</i> Mart.
<i>Conus sinensis</i> Sow., living.	<i>Cassis pila</i> Reeve, living.
<i>Odontocyathus</i> sp. nov.	<i>Flabellum</i> sp.
<i>Nassa verbeeki</i> Mart.	<i>Dentalium</i> sp., living.
	<i>Capulus</i> sp.

These species are nearly all represented by living forms in Philippine waters to-day, so that the beds which enclose them (and they show very little consolidation) are very recent. I would assign them to the Pliocene.

Later alluvial deposits.—Deposits of post-Tertiary origin may be divided into three classes: Deposits left by former streams, by the present streams, and by mangrove swamps.

The old course of the Lanang River northeast of the range of andesite hills in the southern part of the area is marked by a broad belt of stream gravels. The conditions which probably led to this curious change in the course of this river, causing it to adopt a longer one and twice to cut through the range of andesite hills, have been discussed at length in my previous paper¹⁹ and need not be repeated here. A small area of gravels likewise occurs north of this point, marking an older river course of uncertain direction.

The Lanang River has developed a small floodplain between its two gorges. Here a curious abandoned meander also occurs, apparently the incised relic of an earlier course. The gravels here formed the dredging ground operated for a short time by the Lanang Dredging Company. The Luya, a tributary of the Lanang, drains the region in which the Mount Cogran veins outcrop, but I have not been able to learn what were the results of testing in this ground. The lower part of the Lanang River has developed a typical flood-plain, the sides of which slope gently away from the river. This is clearly shown on the map by the courses of the two small streams flowing parallel to it. The one on the south empties

¹⁹ *This Journal*, Sec. A (1909), 4, 6-7.

into the mangrove swamp which is developed at the mouth of the river, but the northern one flows through the paddies, parallel to the main stream for about one kilometer, to a point where a small difference in grade allows it to join the Lanang. The upper portion of the Guinobatan Valley contains a small gravel plain just above the gorge, and in the gorge itself a well-marked gravel bench occurs a few meters above the river level. This portion of the river probably furnishes the most promising location for placer mining to be found in the district, but it has never been prospected properly. The broader flood-plain of the Guinobatan below the gorge was the site of the operations of the dredge of the Oriental and Masbate Company. It is reported that marine clay was encountered at a depth of from five to eight meters. This is not improbable, considering the changes of level which the district has undergone in comparatively recent times.

Except for the swamp at the mouth of the Lanang River, the largest areas of mangroves are not shown on the map, but are found along the southern shores of Port Barrera. Whitford,²⁰ in his report on the timber of the district, estimates the area of mangrove swamp at about 10 square kilometers.

Summary of geologic history.—The Kaal formation, the oldest known in the district, is entirely of sedimentary origin and must have been derived from an earlier land mass of which no trace exists in the district. At some later time the intrusion of a large amount of quartz diorite took place, only a small portion of which is exposed in the area covered by the map. Following this, the land was exposed to long-continued erosion which laid bare the mass of the quartz diorite intrusion. The uplift, which bowed up the southeasterly anticline which to-day forms the backbone of the island of Masbate probably came in late Eocene times. A period of vulcanism accompanied this uplift, during which the dike flows and pyroclastic rocks which constitute the Panique series were formed. The principal period of vein formation followed close upon this. The universal northwesterly trend of the veins is evidence that the fissuring was resultant upon the continued bending up of the anticline. Even later than this period of vein formation, igneous action again took place, as is shown in the dike on the Gold Bug claim. The leucite tephrite is in all probability of the same late date. A little later, or perhaps contemporaneous with the intrusion of these dikes, there was faulting in an east and west direction in the region of the present Guinobatan River. Mineralizing solutions filled these fissures giving the minor series of east and west veins which cut the older and more important series. Probably somewhat earlier than this time the submergence took place which resulted in the deposition of the Mountain Maid limestone,

²⁰ *Min. Resources P. I. Bur. Sci. Div. Min.* (1910), 72.

since on its northern border it seems to be cut off by an easterly vein. However, this isolated occurrence of limestone must remain a puzzle for the present.

After the period of vein formation, submergence and the laying down of the marine sediments occurred; these sediments are now found in their early form in the extreme southern part of the area and in a later phase on the opposite shores of Port Barrera. After the sedimentation had gone on long enough to build up a very considerable mass of conglomerate, sandstone, and shale, a further change of level took place, resulting in an unconformity which is marked by the conglomerate found above the shale. The pebbles of vein quartz and andesite composing this conglomerate show that the Panique formation and the veins were then exposed to erosion and enable us to date the period of vein formation with moderate certainty as between late Eocene and early Miocene. Submergence again continued, giving the series of limestone terraces that form such a prominent feature of the topography between Point Colorada and Point Bugui. It is to be inferred from the courses of the present streams that the Aroroi district itself was at one time, at least in great part, covered by sediments. None of the principal streams shows adjustment to the present topography, and all may properly be classed as superimposed. After the period of sedimentation, the land surface was elevated to a point probably some sixty meters above its present level, and remained at this elevation long enough for a deep valley to be eroded out of the soft shales. Recent depression has converted this valley into the present Port Barrera. Still more recent elevation, but only to the extent of some five or six meters, is shown in the raised coral reefs found on the northern shore of Point Colorada and on the coast east of Buyuan Bay.

ECONOMIC GEOLOGY.

History of mining.—The veins of the Aroroi district have undoubtedly been worked since early times, even before the Spanish conquest.

In the first and second volumes of Blair and Robertson's monumental work are short notices of the mines of Masbate in the reports of the earliest Spanish explorers. An interesting description of the district is given in the account by Gemelli Careri²¹ of his trip around the world. His ship put in at a harbor on the Island of Masbate, evidently Port Barrera, and he describes the mines as follows:

They say *Masbate* is thirty Leagues in Compass, eight in Breadth and proportionably Long. Its Ports are Commodious for any Ship to Water. In it

²¹ A voyage around the world. By John Francis Gemelli Careri, 1695–1698. Translated from the Italian. Published in A collection of Voyages and Travels. Awnsham and Churchill. London (1704), 4, 436.

live about 250 *Indian* Families, which pay Tribute in Wax, Salt, and Civet. But those that dwell in the Mountains, and come from other Parts are more Numerous. Here are such rich Gold Mines, 22 Carats fine, that the Mate of the Galeon St. Joseph, aboard which I went over to *New Spain*, going ashore in one of them, in a very short time dug out an Ounce and a quarter of pure Gold. They do not at present work at these Mines, for want of Industry in the *Spaniards*, who having Commission every Year from *New Spain*, to lay out some hundred Thousands of Pieces of Eight, with an Allowance to them of ten *per Cent*, take no care to look for Gold in the Mines. As for the *Indians*, if they have but a Dish of Rice, they never mind that precious metal and if they gather any in the Rivers, it is when they are press'd for Tribute and then they gather as much as serves to Pay it.

The various members of the Spanish Inspección de Minas, who during the latter half of the last century wrote on the mineral resources of the Philippines, make no mention of Aroroy.

Old workings are found everywhere throughout the district, but with one exception the natives have no traditions as to when and by whom the work was done. The typical form of these workings is deep, narrow, open cuts, now partly caved in, the walls of which show rounded faces as if worked by means of fire. Stone mortars and pestles are often found, showing the primitive nature of the ore treatment. Evidence of workings of later date are found on the Buena Suerte claim on Mount Bagadilla, on Boston Hill, and other places. Here, underground workings of a considerable extent have been carried on and the walls still show the marks of sharp instruments. These workings consist of irregular gophering along rich streaks, sometimes opening out into stopes and again narrowing to inclined passages barely large enough to admit a man's body. The only tradition which the natives have is that an arrastre was worked about one hundred years ago on the northern side of Boston Hill, the southeastern continuation of Mount Kalakbao, the ore being obtained from the old workings on the same hill. The ore here is a hard quartz, and was broken by building fires of the native resin, *brea*, against the face. The ruins of this arrastre are to be seen to-day.

Modern mining dates from the American occupation of the Philippines. As soon as the troops had landed in Masbate, even while the insurgents held the interior of the island, American prospectors began to scour the country and soon rediscovered the Aroroy district. Development work progressed very slowly as capital was scarce, and hence little was accomplished beyond scattered prospect holes. Between 1905 and 1907 the district suffered from an ill-advised boom, during which two dredges and three stamp mills began work. New development work is now under way and the district is now making good progress. The subsequent history of mining operations between 1907 and the present time has been published in the "Mineral Resources" for the years 1908, 1909, and 1910.

The veins.—The veins are confined to the Panique and Aroroy formations, but all of those at present worked outcrop in the former. The

rocks of this series at one time had a far greater thickness over the greater part of the area, and have been largely eroded where not protected by the resistant quartz veins as is the case in Mounts Aroroi, Bagadilla, and Kalakbao. Veins cutting the quartz diorite are to be found in the northern part of the district, but as yet they are undeveloped. No veins of any size have been found cutting the slates of the Kaal formation, although stringers of quartz and calcite are very common. It is not to be expected that large fissures would be developed in rocks of this character as in the resistant volcanics and pyroclastics of the Panique series, and it is reasonable to suppose that if the underground workings on the three hills ever reach the level of the slates, the veins will be found to split up into similar small stringers. This possibility should be borne in mind in estimating the probable continuation of the ore bodies at considerable depth, but otherwise it is merely of theoretical interest as the future of the district is assured if the ore bodies now in process of development continue to hold their values at least as far as the limit of the zone of oxidation. As a rule, the veins are wide and regular. Six meters is not an uncommon width, and some veins can be traced for from 1,200 to 1,500 meters along their outcrops. Transverse faulting is rare, but motion parallel to the veins is abundantly shown, particularly on the footwall. All the important veins follow a north-westerly direction and show very steep dips, those to the north of the Guinobatan River dipping to the northeast at angles of 70° to vertical, while those on the southern side dip to the southwest at angles of from 50° to 80° .

Three veins, the small one on Mount Bagadilla, forming the northern boundary of the Guinobatan limestone, and the Pirate and the Mabel veins, on Mount Kalakbao, do not follow the dominant northwesterly strike, but have a nearly east and west course. They are clearly younger than the main vein system, as the Pirate vein cuts off the El Sol vein, and the Mabel vein likewise appears to fault the two Nancy veins.

The ore.—So far practically all the work has been done in the oxidized zone, and it is only in a few places that the unaltered form of the ore can be seen. This is, typically, a very hard, dark-blue quartz carrying irregular amounts of pyrite, the dark color being due to finely divided particles of manganese oxide; purple amethystine quartz, however, is not found. Successive periods of mineralization are shown by the small veins of more crystalline quartz cutting across the fine-grained, dark quartz which makes up the body of the ore. Faint banding may sometimes be observed near the walls, especially the footwall. In many veins calcite is a prominent gangue mineral in the sulphide zone. It is generally massive and dark blue or dark gray, similar to the quartz. However, it is curious that rhodochrosite (the carbonate of manganese) has never been found in connection with those manganese-bearing calcite

ores, although in similar ores from the Benguet district this mineral is present. The calcite, where found, is generally associated with quartz in more or less parallel bands in the same vein, and when a piece of what appears to be massive calcite is dissolved in hydrochloric acid, it always is found to leave an intricate network of fine quartz ribbons, proving later action of siliceous solutions. The oxidized zone shows a marked change in appearance. Lines of weakness parallel to the walls have acted as channels for the surface-water, with the result that concentration of the different minerals in parallel bands has been accomplished, especially near the footwall where the motion generally has been greatest. The calcite as a rule has been largely dissolved and carried away, although in part redeposited in vugs in the vein and wall rock. The quartz has become leached through the loss of its manganese content, the manganese oxide having been deposited in bands, and, less commonly, patches, sometimes of nearly pure sooty pyrolusite, but more commonly broken quartz covered with manganese oxide. Similarly, the pyrite has been oxidized and deposited in reddish bands of iron oxide. The effects of these changes on the quartz are the forming of "honeycomb" quartz where the calcite and manganese has been carried away. This is generally best developed in the central parts of the veins where the movements have not been so intense and consequently the banding not so pronounced. Another feature consists in the bands of heavy massive quartz found throughout the veins. Where narrow, these are white, although somewhat stained with iron oxide, but in the wider parts they as a rule show an unoxidized core of blue pyritized quartz. All stages of this alteration can be seen in different parts of the district from the first leaching of the blue quartz along small fissures, to the final stage of oxidation where bands of massive quartz a meter or more in thickness have been completely leached. The country rock in the oxidized zone is much altered near the veins, especially on the footwall side, this alteration often extending for several meters from the walls of the vein. The typical alteration product is a brown, clay-like rock generally showing traces of its original porphyritic or fragmental structure, and much stained by manganese. Throughout the district, this decomposed rock, whether of igneous or pyroclastic origin, has the name of "porphyry." It is characteristically cut by a great number of small quartz stringers, and more rarely calcite. These often carry values.

Undoubtedly there is, in such loose material which forms a great part of the veins, a certain enrichment due to the transportation downward of the fine gold, either mechanically or in solution, or by both methods. As a general rule, manganese bearing veins, which at their outcrop may be nearly barren, carry values increasing progressively downward toward the sulphide zone. Developments have not as yet proceeded far enough to determine how important this feature may be, but the fact of the

increasing value in moderate depth is clearly shown in many cases, but most clearly by samples taken in the 30-meter raise to surface from the upper level of the Nancy. In this case there was a progressive increase downward from values of less than 1 gram to over 6 grams per ton. The increase in air circulation in the veins as compared with the country rock, is evidence that the loose nature of the ore in the larger veins may allow mechanical transportation of the fine gold by downward flowing surface waters. An adit run on the vein in the lower level of the Colorado developed the fact that the air was much better than in similar cross-cut tunnels of much shorter length in the country rock. In the lower level of the Nancy, a cross-cut was carried from the side of the hill until it cut the vein at a depth of 90 meters below surface. Before the vein was reached, there was great difficulty with the air, but as soon as the banded, alternate broken and massive quartz was cut, there was found to be a sufficient supply.

It had been considered that the segregations of the different minerals into bands must affect their values, and it was taken for granted that the more massive bands of quartz were practically barren, but careful sampling did not confirm this prediction. As a rule, it may be said that the best values occur in rather irregular pay streaks, which have a tendency to follow the footwall.

The prospects are not so favorable in the sulphide zone. The hard, blue quartz will, of course, be more expensive to mine and mill than will the broken material handled in the oxidized zone, and whatever has been added to the values by concentration from above, will be lacking at this level. However, practically all the work so far has been done in the deep oxidized zone, and the depth to which the latter has been shown to extend insures the future of the district.

The comparatively great depth of the zone of oxidation found here, considering the low elevation of the district, is consequent upon its recent geologic history. The evidence of the drowned valley of port Barrera, and to a less degree of the Lanang River, shows that the land in recent geologic times stood at a level probably over 50 meters above its present elevation. It remained at this level long enough for a broad valley to be eroded and consequently long enough for the oxidizing surface waters to reach a greater depth than would have been possible under conditions existing to-day. Consequently, it will probably be found that while the sulphide zone domes up under the hills, the curve which it follows will be much more gentle and the zone of oxidation deeper than would otherwise be the case.

In the oxidized zones of different veins, some difference of values is to be noted between the veins carrying noticeable amounts of manganese and those in which iron oxide forms the metallic portion of the gangue. As far as a limited observation extends, all the veins which on their

outcrops show rich ore are those in which manganese oxide is not prominent, such as the Gold Dollar vein on Mount Aroroy, the Red Oxide vein on Mount Bagadilla, the El Sol vein on Mount Kalakbao, the small veins on Boston Hill, and others. Evidence from development work, though very meager, seems to show that the values in these veins do not increase downward in such a satisfactory manner as in those bearing manganese, which are as a rule barren, or nearly so, at the outcrop. The values in some at least of the non-manganiferous veins, seem to decrease greatly a few meters from the surface.

In this connection a recent paper by W. H. Emmons,²² on the agency of manganese in the superficial alteration and enrichment of gold deposits, is of great interest. Roughly stated, the hypothesis presented is that the presence of manganese in the upper portion of a gold-bearing vein aids greatly in the solution and downward transportation of the gold by the action of surface waters carrying chlorine, the gold being redeposited nearer the sulphide zone. Such being the case, non-manganiferous veins would show higher values on their outcrops, due to the transportation of valueless constituents, and, conversely, lodes carrying manganese will be poor at the outcrop and increase in value in depth, owing to the downward transportation of gold in solution. Similarly, placers would be developed from non-manganiferous lodes, but not as a rule from those carrying manganese. Much evidence derived from chemical experiments and from a study of the ore deposits of the United States is adduced in support of this view.

It is interesting to note, with regard to the veins of the Aroroy district, how closely the facts observed agree with this hypothesis. Except for the placers, where the evidence is inconclusive owing to the occurrence close together of manganiferous and non-manganiferous veins, the facts in regard to values in the veins themselves bear out the hypothesis completely. The fact that the district is bounded on the north and west by salt-water is also in favor of this hypothesis. Hence, the proportion of chlorine in the mine waters should be above the average and the solution of gold facilitated. However, one point weakens this evidence. This is that in the best developed veins, that of the Colorado Mine on Mount Bagadilla and the Nancy veins on Mount Kalakbao, the ore is much shattered and banded, (Plate II) affording open channels for the descending waters to transport the fine gold mechanically. Further development work in this district will be watched with especial interest, as, with the conditions existing here, of veins carrying varying amounts of pyrolusite and others free from this mineral occurring close together and apparently the result of the same conditions, important evidence may be found bearing upon Emmons's hypothesis. Another point upon which the evidence of development work will be awaited with interest is the effect of the calcite (which in most of the veins seems to be present in increasing amounts away from the surface) upon the values.

The close juxtaposition of manganiferous and non-manganiferous veins

²² *Bull. Amer. Inst. Min. Eng.* (1910), No. 46, 767-838.

is another feature which can not satisfactorily be explained at present. Possibly the lenses of manganese ore, present in the slates of the Kaal formation, are of earlier origin than the veins, and the ascending solutions following fissures cutting through these bodies brought up the manganese oxide, while others not so situated are lacking in this constituent, or it may be that the different types of veins are indicative of different periods of mineralization.

The gold is only about 25 per cent free milling, apparently due to the manganese oxide and, although alloyed up to 10 or 20 per cent by weight with silver, contains practically no copper, and the ore is well suited to cyanide treatment.

Individual properties.—It is my purpose to give short notes on the properties which at the time of my last visit were furthest developed. The fact that many are omitted is no evidence that they may not be as fully worthy of consideration as their more developed neighbors, but in a region where work is progressing so rapidly as in the Aroroi district to-day, it would serve no good purpose to multiply descriptions which rapid development is rendering obsolete.

The Keystone Mining Company has developed one vein on Aroroi Mountain by means of two shafts 85 meters apart and connected by a drift at the 20-meter level sunk on the vein at the top of the hill. The deeper shaft now reaches a depth of 42 meters. The ore differs from the type commonly met with in that there is a far smaller amount of manganese present than in other veins of the district, and the characteristic banding observed elsewhere is lacking. The ore is a white quartz, stained red with iron oxide and to some extent honeycombed. The quartz is much shattered and shows subsequent mineralization in the shape of many small quartz stringers cutting the vein in all directions. The ore is oxidized throughout to the bottom of the shaft; however, the larger pieces of quartz often show cores of the characteristic bluish quartz carrying a considerable proportion of pyrite.

The Colorado Mining Company controls a group of claims on Mount Bagadilla. The veins outcrop on this property, the best developed of which is known as the "No. 5." This has been opened by drifts at elevations of 230 meters and 290 meters above sea-level, connected by an incline shaft in the footwall, and winzes sunk to a depth of 50 meters below the lower level. This vein, which is about 5 meters in width, shows the most beautifully marked banding of any in the district, particularly near the footwall. The values run rather irregularly, but a fairly well defined pay streak of about 2.5 meters width on the footwall side, although generally separated from the footwall by 0.5 meter or less of lower grade material, carries the richer part of the ore. On the hanging wall side the decomposed andesite carries values for about 1 meter from the wall of the vein, these probably being contained in small quartz stringers which are found near the vein. A curious feature is that the vein makes a sharp turn toward the northeast at a considerable distance from the portal of the adit, its normal course being northwest. It follows this new direction for about 8 meters and then resumes its northwesterly course, apparently due to a pre-existing north-easterly fault.

Another vein on the Buena Suerte claim of the Colorado Company's property, to the southwest of "No. 4", shows ancient workings of considerable extent.

These are not in the vein itself, which is largely hard massive quartz, but in the decomposed andesite on the hanging wall where small rich stringers had been followed by the early miners in irregular stopes and passages.

The Montana vein now being prospected by the Aroroy Mining Company lies on a spur extending toward the northwest from Mount Bagadilla. This vein can be traced from the gorge of the Guinobatan River northwesterly for a distance of some 1,500 meters. It is narrower than the average for the district, varying from 1 to 3 meters in thickness, and, as it is nearer the water-level, the ore is less oxidized than in others. Banding is entirely lacking, the oxidized portions of the ore showing irregular honeycombing. Although rich ore has been discovered at various places and a line of ancient open cuts shows that the surface ores were formerly worked to some extent, development has not yet proceeded far enough to determine the importance of this vein.

The deposit formerly worked by the Gold Bug Company and now being explored by the Aroroy Mining Company is located on the western end of Mount Kalakbao. The rock here consists of an irregular deposit of sandstone, shale, and conglomerate, apparently all derived from the andesites and pyroclastics of the Panique formation, which form the mass of the mountain. These sediments are cut here by a basic dike of uncertain composition, but allied to the leucite-tephrite found 3 kilometers north of this dike. Small veins of blue quartz up to 1 meter in width, and oxidized only to a depth of about 1 meter below the surface, also cut these sediments. The shale is the lowest of the sediments and is found only near the basic dike in the Gold Bug open cut. It is nearly black and is heavily impregnated with pyrite along its cleavage planes. Under the microscope it is seen to contain numerous, fresh, angular fragments of plagioclase feldspar. It carries small values in gold, probably never exceeding 4 grams to the ton. The sandstone and conglomerate lie above the shale and grade into each other irregularly in a way to suggest stream deposition. These rocks in irregular areas along the surface contain values, and lines of old native workings are found in many places. The ground was explored by the Aroroy Mining Company in a series of open cuts. These show the sandstone to be deeply iron-stained and oxidized almost to the consistency of clay for a depth of from 2 to 5 meters from the surface, where it changes rather suddenly to a blue, but still somewhat decomposed, rock more or less impregnated with pyrite. Values of 30 grams and over per ton are often obtained in the shallow oxidized zone, but where the color changes to blue and the rock becomes firmer, the values soon sink to 5 grams or less. Apparently, the whole deposit is the result of filling of the open spaces of the sandstone by mineralizing solutions and in the oxidized zone this has been greatly enriched by residual concentration.

The El Sol vein occurs farther east on Kalakbao Hill. This consists of iron-stained quartz, partly honeycombed but not banded, which may be the continuation of the Montana vein. Rich ore has been found in places, but at the time of my last visit no great amount of development work had been done. The southeastern extension of this vein is cut off by the Pirate vein extending nearly east and west, one of the few in the district which do not follow the northwesterly strike.

The Syndicate Mining Company is working a group of claims on the central part of Kalakbao Hill.

The principal vein is known as the Nancy No. 1, and shows a width of 16 meters although not all in workable ore. The ore shows well-defined banding near the footwall, and is much broken and oxidized in the central and hanging wall portions. In the lower levels calcite forms a small proportion of the gangue. The assays show extremely irregular values, but the greater part of the richer

ore, assaying 10 grams or over to the ton, occurs in irregular masses near the footwall. The Nancy No. 2 is situated near this vein and branching from it. This is smaller than the preceding, but contains patches of rich ore. The two veins join on the surface some distance to the southeast and also appear to approach in depth. Both seem to be cut off by the Mabel, an east and west vein nearly parallel to the Pirate vein, and about 300 meters to the south. An inclined fault, approximately parallel to the strike and following the grade of the steep hillside, seems to have displaced the upper portions of both veins. The upper level is for the most part less than 30 meters below surface, and the larger vein has rather irregular boundaries, surface slipping having greatly confused the relations of ore and country rock. As the vein forms the summit of the hill, the steep slope on the eastern side is deeply covered by a talus consisting almost entirely of quartz fragments. The ancient miners found this a profitable field, for stone mortars and pestles are found here in great numbers. It has been proposed to work this on a larger scale, but preliminary sampling by a series of small pits and open cuts, which, however, were not continued to bed rock, did not show sufficiently satisfactory values.

Another group of four veins has been developed to some extent by the same company on the Nebraska Star claim, some 400 meters to the east. Here the veins are narrower, at the widest never exceeding 4 meters, and then seem to pinch out to the northwest. The two which are farthest to the east are united at the surface and separate some 4 meters below. The ore, especially in the larger vein, is somewhat less oxidized and contains more calcite than in the Nancy veins. The best examples of the blue-gray calcite are to be found here. A mass of oxidized, iron-stained quartz occurs on the Have Got claim, about 400 meters southeast of the Nebraska Star veins, and possibly is a continuation of them. The workings have been caved for several years so that nothing definite could be learned of its relations. It appears to be a rather irregular, funnel-shaped body, possibly a local widening of smaller veins. The country rock surrounding this deposit is also reported to have carried a considerable proportion of values.

The above comprise the more important veins of the Aroroy region as now developed. Boston Hill, the southeastern continuation of Kalakbao, is known to contain several veins, one of which, rather narrow and of white quartz stained with iron oxide, shows in places unusually high values at the surface.

An interesting series of ancient workings on the Gilt Edge claim, on the southern end of Mount Kalakbao along a vein which, contrary to the usual rule, contains, even at the surface, a large proportion of calcite, can be seen to this day.

The property of the Tengo Mining Company is located 6 kilometers to the south of Mount Kalakbao. Here, one large vein, with possibly others parallel to it, outcrops on a spur of Mount Cogan. Not enough development work has been done as yet to determine with any certainty the relations of these veins. The ore is a somewhat brecciated quartz much stained with iron oxide, and in places near the surface carries values much higher than the average for the district. No extension of the Cogan veins to the northwestward has been found. There is no evidence that they have any tendency to pinch out at the northwest end of the spur, and it is possible that they are cut off by a fault.

Higher up the Guinobatan River to the east of Mount Vil-lon is a group of veins now worked by Mr. Hayes and his associates. These do not seem to follow the dominant northwesterly trend exhibited in the Aroroy district, but are supposed to form a network. Other deposits are said to exist in the main range still farther to the southeast, and it is quite probable that further prospecting will develop new districts in this inland region.

Other metals.—Several manganese claims have been staked in the areas of red slates to the east of Balangting Creek and west of Mount Vil-lon, but no development work, and hardly even assessment work, has been done. As far as can be seen, the manganese ore, psilomelane, occurs in lens-shaped bodies lying parallel to the slaty cleavage. Prospecting alone will show whether any of these lenses may prove to be of sufficient size for profitable exploitation.

Pebbles and boulders of a hard, massive hematite are often found in Aroroy Creek, northeast of Aroroy Mountain, but the outcrop from which these are derived has not yet been discovered. As this is near the southern boundary of the diorite intrusion, it is possible that the hematite may be a contact deposit on the border of the diorite.

An outcrop of a small vein of iron-stained quartz which shows small specks of chalcopyrite with malachite and azurite, occurs on the Have Got claim of the Syndicate Mining Company, on the southeastern slope of Mount Kalakbao. This is of no commercial importance, and is interesting only as being the sole occurrence of copper minerals known in this district.

On the eastern flank of Mount Bagadilla, east of the property of the Colorado Company, is a vein in which small specks of galena have been found.

MINING CONDITIONS.

Location.—Natural conditions are extremely favorable for cheap mining in this district. All the more important veins outcrop near the summits of steep hills, making possible a large amount of preliminary development work by means of adits. The ground, whether country rock or ore, stands well, and comparatively little timber is necessary. The deep zone of oxidation is, of course, a very favorable point and even if the ore bodies should not be found to be of workable grade in the sulphide zone, there is undoubtedly enough oxidized ore available to make mining profitable.

Transportation.—The more important mines are situated from 2 to 5 kilometers eastward from Port Barrera, which is as perfect a harbor as can be desired. At present the steamers anchor off the village of Aroroy and the freight is landed in small boats. From Aroroy a good provincial road runs to the Gold Bug mine, a distance of 7 kilometers, and is continued by private companies up the cañon of the Guinobatan. It is planned eventually to build a dock near Maguilanguilan Island and a road from there to the mines. This will make lightering unnecessary and will shorten by half the distance to the mines and will offer a much more sheltered harbor. Transportation is at present furnished by a fortnightly steamer from Manila, with occasional extra boats, and the run is made in about twenty-four hours.

Timber.—The greater part of the mining district and, indeed, the

whole central range of the island, is heavily timbered. The district in this respect has a great advantage over others. Mine-timbers at present, are taken from the immediate vicinity of the mines, being cut by natives on contract.

Mr. Herbert, of the Colorado Company, has kindly furnished me with the following list of the species: ²³ Molave (*Vitex parviflora* Juss.), dungon (*Tarrietia sylvatica* Merr.), cubi (*Artocarpus cumingiana* Tréc.), bansalaguin (*Mimusops elengi* L.), matamata colorado (*Strombosia* ?), and matamata blanco (*Strombosia philippinensis* Rolfe).

Woods available for temporary timbering, as for example in stopes which eventually are to be filed, are lauan (*Shorea* sp.) and to-og (*Bischofia javanica* Bl.).

These timbers have been given in the order of their preference.

The following average prices, in Philippine currency, were paid for timber in 1909:

	Pesos, ²⁴
First group, one piece 7 feet long, squared 7 inches (in some cases only molave accepted)	1.00
The same, rough	0.75
Lagging (molave boards or poles of other first group wood) per running foot	0.01-0.02
Ties 4 feet by 4 inches by 4 inches; each	0.10-0.12

Besides the heavily-wooded central range of the island there is a large amount of excellent timber just across the bay from Aroroi, so there need be no fear of future shortage, if reasonable care is taken.

A more detailed study by Whitford of the forest conditions of the Aroroi district has recently been published.²⁵

Power.—The Guinobatan River runs nearly dry during the dry season and is subject to sudden heavy floods during the rainy season; although there is a good dam site just below its junction with the Kaal, it is doubtful whether the river will be valuable for water power. The Lanang River, on the other hand, drains a much larger district, has a more regular flow and a greater volume of water. A good dam-site exists at the falls in the upper gorge.

The mills and dredges previously in operation have used fuel from the large mangrove swamps on the eastern and southern shores of Port Barrera. Whitford ²⁶ estimates that the available mangrove swamps cover an area of about 10 square kilometers, but makes no estimate as to the amount of firewood available per hectare. The cost delivered at the mills and dredges varied from 4.00 to 5.00 pesos per cord and roughly estimated to be equivalent to rather less than one-half ton of Australian

²³ Botanical names furnished by Elmer D. Merrill of the Bureau of Science.

²⁴ One peso Philippine currency is equal to 50 cents United States currency.

²⁵ *Min. Resources P. I. Bur. Sci., Div. Min.* (1910), 72-78.

²⁶ *Loc. cit.* 77.

coal. The mangrove swamps, while affording a large amount of good firewood, are by no means inexhaustible, and when large mills start in the district the supply will be insufficient. Coal of fair grade is now being mined by the East Batan Coal Company and sold at its mine for 6.50 pesos a ton. The Cebu deposits should soon be producing. Promising coal deposits, as yet unworked, occur between Dimas-Alang and Kataingan on the Island of Masbate itself. Hence, even if it is not found advisable to develop water power in the district, or if the power available is not sufficient, there need be no fear of a shortage of fuel.

Labor.—Aroroy is now in a better condition than the other districts in regard to labor. Work has been going on for a sufficient time to build up a class of fairly efficient miners (Plate III), and at present the local supply is more nearly sufficient for the demand than elsewhere. The natives finally have been educated to the point of working by contract, a method which has been found to be most satisfactory for all concerned, especially in the smaller workings, as the laborer works harder and generally receives a larger amount of money than if working by the day, and the employer is relieved of the necessity of such close supervision as is required when miners work for wages. The wages paid in the district are: Laborers and muckers, 0.60 peso per day if food is furnished, or 0.80 peso without food; miners, 0.80 peso per day with food, or 1 peso without; foremen, blacksmiths, etc., from 1.50 pesos to 2 pesos per day.

During the next two years, when several companies start operations on a large scale, there may be a temporary shortage of labor, but I do not expect any permanent trouble from this cause, as laborers are beginning to come in of their own accord from northern Panay and Sibuyan and there should be no great difficulty in importing others if it became necessary. I have been told that, under average conditions, 9 men working 3 to a shift six days in the week, and doing their own mucking, can advance a tunnel 3 feet per day in "porphyry" and 1.5 feet per day in hard fine-grained rock. Owing to the irregularity of the native as a laborer, it will always be necessary to have at call a larger force than actually is necessary at any one time. There may be considerable difficulty in keeping a full force at work on Sundays and holidays, but I believe enough men could always be counted on to keep a mill running steadily. The company stores and laborers' houses, and a system of fines for absences without permission, have already done much to correct the unsteadiness of native labor.

ILLUSTRATIONS.

PLATE I.

FIG. 1. View of the southern part of the Aroroy district looking south from Mount Bagadilla; Mount Kalakbao in the foreground, Mount Vil-lon on the extreme left. (Photograph by Ferguson.)

2. The Aroroy district looking south and east from across Port Barrera. The two hills in the center are Mount Aroroy and Mount Bagadilla. Mount Kalakbao is partly concealed by the latter. (Photograph by Ferguson.)

PLATE II.

Upper level of the Colorado Mine, showing the banding of the ore. (Photograph by Ferguson.)

PLATE III.

Group of native miners at the office of the Syndicate Mining Company. (Photograph by Ferguson.)

MAPS.

1. Map of Masbate. (From Atlas de Filipinas, with corrections by H. G. Ferguson.)

2. Geologic map of the Aroroy mining district, Masbate.





FIG. 1.



FIG. 2.

PLATE I.



PLATE II.



PLATE III.



MAP 1.—MAP OF MASH

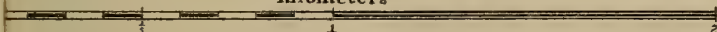


MAP 1.—MAP OF MASBATE. (From Atlas de Filipinas, with corrections by H. G. Ferguson.)



Scale

Kilometers



0 1 2



REVIEWS.

Allen's Commercial Organic Analysis. Volume III. 4th ed. Cloth. pp. x+635.
Price \$5 net. Philadelphia, P. Blakiston's Son & Co. 1910.

This volume is entitled Hydrocarbons, Bitumens, Naphthalene and its Derivatives, Anthracene and its Associates, Phenols, Aromatic Acids, Gallic Acid and its Allies, Phthalic Acid and the Phthaleins, and Modern Explosives. A table for the comparison of Centigrade and Fahrenheit degrees covers 10 pages, and the index 5 pages.

While the value of this volume is not to be denied and it will be much appreciated and find application in every chemical laboratory, it is open to objections. The critic realizes that every user of this book will find portions to meet with his highest praise and other parts which will not appeal to him. Since the volume is part of a work on "Commercial Organic Analysis" it is perhaps not just to expect too much; yet in some places the treatment of the subjects under discussion is more than ample and leads one to expect too much, perhaps, in other places. A pleasing amount of detail, theoretical discussion, and references are noted in some parts of the book and other portions are merely a collection of more or less crude, analytical processes as employed by the hurried analyst. In this respect the work is not well balanced, a condition to be expected since each author follows his own bent.

It is with regret that one notes the rapidity with which a work of this nature becomes antiquated. The volume is hardly from the press before many new and valuable processes, not included, are in use. The treatment of cellulose nitrates and nitroglycerine and of the explosives of which these compounds are the ingredients of chief importance is very satisfactory, but the consideration of blasting explosives in general is very incomplete and the methods given will prove adequate only in the analysis of the majority of smokeless powders and of dynamites, gelatine dynamites and blasting gelatines of a comparatively simple composition. Practically no mention is made of potassium chlorate, ammonium nitrate, nitronaphthalene, nitrostarch, trinitrotoluene, and other explosive compounds, the use of many of which is rapidly increasing.

A very large proportion of modern blasting explosives is intended for especial purposes and modified to secure absence of excessive fumes, flame, and deterioration under conditions of great moisture or cold. The analyst should be informed as to the more common methods by which these ends are attained in order that his examination may be made intelligently.

While special problems must occasionally be encountered it is possible to devise a general scheme of analysis which will prove adequate for the examination of the great majority of explosives. None of the general methods as yet published give general satisfaction in actual practice.

A few of the omissions noted, either of work appearing since the writing of the book or purposely not mentioned are:

Pages 267 and 270. Retene, Bucher, *J. Am. Chem. Soc.* (1910), 32, 374. Page 293, the work of Kohn and Fryer and J. Walter, concerning the coloration of phenol is still quoted as authentic. (See *This Journal*, Sec. A (1908) 3, 361 and (1909), 4, 133.) Page 340, Willstätter and Majima's work is not mentioned in connection with the estimation of quinone, *Ber.* 43, 1171.

Few typographical errors are noted and the printing and type are excellent.

H. D. G.

W. C. H.

Allen's Commercial Organic Analysis. Volume IV. Edited by Henry Leffmann and W. A. Davis. 4th ed. Cloth. pp. x+466. Price \$5 net. Philadelphia, P. Blakiston's Son & Co. 1911.

This volume is composed of the following divisions: (1) Resins, by M. Bennett Blackler, 103 pages; (2) India Rubber, Rubber Substitutes, and Gutta-percha, by E. W. Lewis, 57 pages; Hydrocarbons of Essential Oils, by T. Martin Lowry, 25 pages; Ketones of Essential Oils, by T. Martin Lowry, 28 pages; Volatile or Essential Oils, by E. G. Parry, 85 pages; Special Characteristics of Essential Oils by Henry Leffmann and Charles H. La Wall, 128 pages; Tables of Essential Oils, 30 pages; and an Index, 4 pages.

The volume is admirably arranged, and contains much new matter not found in the older editions. It will unquestionably prove of great value as a reference book for analysts.

The treatment of Manila copal has not been brought up to date and no reference is made to the investigations on that subject carried out at the laboratory of the Bureau of Science which have not confirmed in every respect the earlier work of Tschirch and Koch.

The treatment of certain other subjects is also, perhaps, not as complete as might be desired. For example, only one method, namely, the iso-bornyl acetate method, is given for the passage from pinene hydrochloride to camphene, in the preparation of artificial camphor, whereas we understand that several methods, equally as good are now employed.

However, in general this volume offers but little chance for adverse criticism and will be found to attain the high standard of the previous volumes of the same edition.

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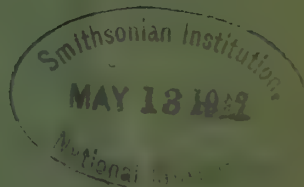
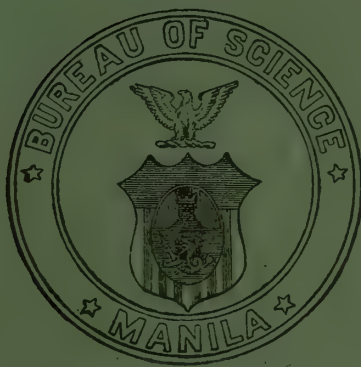
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No. 6

ADDITIONAL NOTES ON THE ECONOMIC GEOLOGY
OF THE BAGUIO MINERAL DISTRICT.¹

By WARREN D. SMITH and FRANK T. EDDINGFIELD.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

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I. GENERAL GEOLOGY.

INTRODUCTION.

In his notes on the Geology and Geography of the Baguio Mineral District,² Eveland discussed the various classes of igneous rocks in this region. It will not be necessary to add many details to his description but it is necessary to give some further statements regarding distribution and relationships.

¹ An extended description of the various mining properties in this district has already been prepared and will be included in The Mineral Resources, 1911, and also in one of the technical journals in the United States.

² *This Journal*, Sec. A (1907), 2, 207.

IGNEOUS ROCKS.

The diorite.—Every gradation between diorite and andesite is found in the Benguet region, the differentiation being largely a matter of depth. The distribution of the diorite is somewhat different from the way it is shown on the 1906 map. We found during our recent examination that typical diorite is much less common than was formerly thought to be the case. In fact, the predominant rock is andesite and not diorite. The principal development of the diorite is in the Antamok Valley just below the Benguet Consolidated Mill. Here the rock can be found in large, fresh masses in the hill side.

J. P. Iddings who spent four months in 1909–10 in the Philippines studying the rocks both in field and laboratory, describes this rock as follows:

At Antamok, Benguet Province, there is a medium-grained quartz-diorite with inequigranular consertal fabric. It consists of plagioclase and considerable brownish-green hornblende, anhedral with respect to each other, but euhedral toward quartz and orthoclase. There is some altered biotite. In places the orthoclase is intersertal to poikilitic, with inclusions of plagioclase and hornblende.³

In the analyses of the diorite on page 224 of Eveland's article a correction should be made in the first three samples. Plainly the alumina is far too low and the ferric oxide much too high. The proportions as given in No. II are more nearly correct, namely, Al:Fe = 2:1.

The principal rock in the region is andesite. It has its greatest distribution in the eastern half of the district, where it is found on the highest hills and in the lowest valleys. This rock is often mistaken for diorite, but while it does have dioritic phases it occurs as a porphyritic rock in nearly all exposures examined. As a typical andesite and a typical diorite can originate from the same parent magma and vary through the difference in rate of cooling, we do not necessarily find a sharp line between the two as has heretofore been considered to be the case in this region. We have been unable to draw such a line save in one place, namely in the lower Antamok Valley near the Camote property, and here the diorite is a later intrusion, cutting off the Camote vein sharply.

The Tertiary lavas.—The Tertiary lavas comprise earlier andesite, later andesite, and intrusives. In the deep valleys we find the finer grained and also more nearly holocrystalline varieties. It is difficult to locate the contact, but the great difference between this and the variety found on the high levels makes it fairly certain that there is a time break. In fact, in Major Creek we have found a series of sediments, not easily traced it is true, but plainly shown at one or two points, which

³ *This Journal*, Sec. A (1910), 5, 169.

lie between these two andesites. The andesite in the cañons below is much finer grained and has the following characteristics:

The lower andesite.—Sample from Gold Creek near Kelley's mine.

Megascopic.—There are two principal facies exposed here, light and dark. The dark facies has the appearance of a typical andesite, bluish gray in color, dense black ground-mass with short stumpy plagioclase crystals with glistening surfaces. The rock is quite even in texture. The light phase has a "pepper and salt" appearance, with innumerable green specks, which are hornblendes. Both specimens are fresh and hard, breaking with conchoidal fracture.

Microscopic.—Both facies are quite porphyritic. The light phase contains plagioclase, amphibole, and magnetite in an holocrystalline ground-mass of quartz and feldspar. No quartz phenocrysts were seen. This is a typical hornblende andesite. In the dark phase we have plagioclase (labradorite) both augite and hypersthene pyroxenes, all these occurring as large and small phenocrysts in a cryptocrystalline ground-mass of quartz and feldspar with some glass. Magnetite is common. The feldspars are marked by the inclusions they contain.

The upper andesite.—This formation is widely distributed on the summits of the majority of the ridges in the eastern portion of the district, but is particularly well shown along the Kias ridge above the Major Mine. This rock has the following characteristics:

Megascopic.—This rock has not by any means as fresh an appearance as the lower andesites, for the reason that the upper andesite is more exposed. On fresh surface the rock appears gray. It has larger and fewer phenocrysts than those just described.

Microscopic.—The slide shows plagioclase and smaller augite phenocrysts in a ground-mass which is distinctly glassy. Magnetite is abundant. The rock in thin section reveals considerable decomposition of the minerals which can not be seen with the naked eye.

Andesite breccia.—Eveland has already described this formation under the name of tuff.⁴

While there is some tuff included in this formation, it consists mainly of irregular fragments, large and small, of coarse and fine-grained andesitic material, and would be called more properly an agglomerate, as the constituents are of a heterogeneous nature. Eveland's term "eruptive conglomerate" was meant to convey the idea of two distinctive characteristics, namely, the volcanic origin and the heterogeneous make-up of the mass. Therefore, we shall refer the reader to his description of it as further attention to it in this paper is unnecessary.

INTRUSIVES.

Eveland has already discussed this class of rocks in the Baguio district. We shall add nothing here to his description, but later work has shown the necessity of modifying a statement which he makes on page 226 of the discussion already referred to: * * * "*Many small dikes*

⁴ *This Journal, Sec. A (1907), 2, 231.*

of basalt cut through this rock (diorite); but they are unimportant, excepting that the directions of the dikes seem to be quite uniformly along east and west lines. In common with the system of ore deposits in the diorite (andesite), the majority of the veins striking east and west, or approximately in that direction, this prevailing direction would point to a line, or rather a direction, of weakness in the main mass of the rock." A great many of the veins in the district, I mean the important veins, do not strike in an east and west direction, but in a large number of cases northwest and southeast.

The principal intrusion of the district is the large mass of quartz diorite already referred to, in the lower part of the Antamok Valley. Here it forms one wall of the Camote ore-body and cuts it off sharply, so that the vein is not found on the western side of the river. The many small basalt dikes do not appear to bear any relation to the veins.

SEDIMENTARIES.

The Major Creek formation.—We have already referred to some sediments which are to be found occurring beneath the later andesite of Major Creek. The exposures are not extensive, nor are they traceable for any great distance. They consist of shales, sandstone, and conglomerate, but no limestone was found. The thickness is not great, apparently not over 100 or 200 meters.

The conglomerate has an oxidized, sandy matrix and pebbles derived from the andesite beneath. It is fossiliferous. The fossils are of comparatively recent forms. We correlate this formation with the conglomerate in the Trinidad Water-gap.

The sandstone is best shown in the gulch just below Mansion House. Here it is yellowish-white, and extremely hard, the sand grains having been recemented by the silicious waters which poured out at many points in this region at a later period. These will be referred to later.

The shale, which is gray in color, is best seen at the entrance to the Engineer tunnel on the Major Mines property. It is somewhat brecciated and in places it also has been recemented by silicious waters. Red ferruginous-shale also has been seen in this locality.

The absence of the limestone here is accounted for by erosion, and the comparative thinness of these formations at this point by the fact that the old shore line was approximately in this place. These same sediments outcrop again in the Benguet Road, and on either side of the Santo Tomas Trail. Eveland, in discussing the western portion of the District, has already pointed out the occurrence and characteristics of these sediments.

The Baguio formation.—We have given the name of the Baguio formation to all the more or less silicified and metamorphosed deposits which cap the highest hills around Baguio, particularly in the vicinity of Government Center and Camp John Hay. In places the formation

consists of a fine-grained, loose deposit of silica, nothing more or less than silicious sinter. At others it is an exceedingly hard chert, at still other points it can be seen that it is plainly an altered andesite, or again, a metamorphosed limestone.

At the time when the fissures in this country were being filled with vein matter by ascending silicious waters, many springs existed throughout the region, in fact there are some left at wide intervals. It was at this period, it is reasonable to suppose, that the various formations, now found in an altered condition, were permeated by these waters and many of the original constituents replaced by silica.

Thin sections of samples taken from this formation have been prepared and examined with the microscope and show most conclusively just what has taken place. One specimen, which looks like chert when seen with the naked eye, shows when examined with a high power petrographic microscope, that the rock was originally a porphyritic andesite. The outlines are intact but the interior of the crystals is filled with *secondary* cryptocrystalline quartz (Plate I).

A place occurs on the "Military Cut-off" road just south of Government Center where formerly one of these hot silicious springs was located. The material is almost snow-white, very fine, and can be scooped out as if it were loose sand. Some of this sinter has been assayed and found to carry from 80 cents to 1.40 dollars in gold values. An analysis of this material shows that it is made up of about 94 per cent of silica.⁵

The later sedimentaries.—These have already been described by Eveland in the article referred to. Further mention of the limestone will be made in the chapter dealing with economic materials.

GEOLOGIC HISTORY.

The Baguio region was comparatively high ground when that about Manila and the Visayan islands was under water. The rock consisted of diorite and perhaps old sediments, the age of which we do not know. This land-mass was eroded, the sediments being deposited in the sea around it.

A volcanic period set in during which andesite flows spread over the country, covering the sediments where they overlapped the basal mass. The region then sank until the basal igneous mass in part was about at, or perhaps below, sea level. A great reef-building period then ensued and a considerable thickness of limestone was deposited. At the close of the Miocene, the land began to rise. This was the geological event known as the "Miocene Revolution," which occurred throughout the distance from Spain to the Philippines. At this period the great chains

⁵Analysis by A. P. West, laboratory of physical and inorganic chemistry, Bureau of Science.

of mountains including the Pyrenees, the Alps, and the Himalayas were thrust up. Contemporaneous with this occurrence there had been a great intrusion of andesitic and dioritic rock beneath the later sediments.

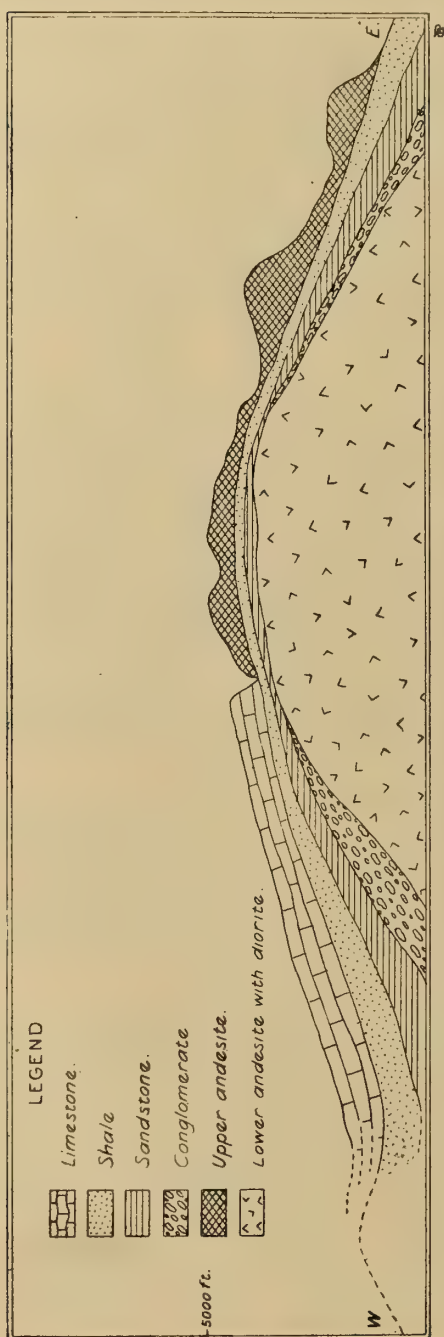


FIG. 1.—Ideal section through the Benguet region east and west.

At the same time, and as a consequence of the stresses set up in this rising and bending mass, fissures opened, running in various directions through the rocks, and hot silicious and calcareous waters made their way to the surface, filling the fissures with vein matter and to some extent metamorphosing the surface rocks. The hot silicious waters carried some gold in solution and deposited it in these fissures. Subsequent erosion has removed much of the upper portions of these formations and carved out the fine cañons the scenery of which we now enjoy.

The elevation alluded to as the "Miocene Revolution" amounted to at least 1,500 meters. To-day, in Trinidad Water-gap fossil coral occurs at an elevation of 1,335 meters and it has been found at a much greater elevation farther north.

STRUCTURE.

To obtain a clear idea of the structure of this region it is necessary to draw upon our knowledge of the geology of a larger area than is shown on the map accompanying this report. The sediments, which we see now in a more or less broken condition on the flanks of the highlands,

formerly extended over this central region in a great arch, as shown in the ideal section (Fig. 1).

The fissures now occupied by the veins seem to follow some definite system, northwest and southeast, and they doubtless have, in turn, some definite relation to the torsion set up during the uplift of the region.

In the Bued River I noted the jointing in the andesite as follows: One system running north 15° west and another north 38° east. I have not found any special correspondence between these systems and the veins of the district. However, there seems to be some general similarity throughout the different parts of the Archipelago in the matter of the larger fissures; namely, that the northwest and southeast system is the major one. (W. D. S.)

THE MINERAL VEINS.

The types of mineral veins.

1. Calcite and quartz, with manganese, galena, iron, and free gold:
 - a. Headwaters. A vein 5 to 8 meters wide in the west; high in calcite usually on the hanging wall, carrying some pyrite and galena. In the east, quartz manganese on foot and hanging walls, often barren between. Values irregular, in large lense-like masses.
 - b. Camote. Characterized by ribbon or banded structure of calcite, and manganese; with granular segregations of quartz throughout, irregular in a vein 8 to 15 meters wide. Very large amounts of manganese make the vein very black.
 - c. Gomok. Mostly calcite with some galena in an irregular vein. Marked banded structure with considerable manganese and in places some galena and copper.
 - d. Antamok Valley. Calcite gangue banded with manganese; veins 1 to 1.5 meters wide.
 - e. Madison. Several nearly pure calcite veins, in some cases showing a marked banded structure due to manganese.
2. Quartz veins with some pyrite and free gold and in some cases manganese, galena, or copper:
 - a. Kelley (south slope). A much oxidized quartz vein 3 to 10 meters wide with rich streaks throughout; indefinite walls.
 - b. Muyot. Strong vein 3 to 6 meters wide with some rich streaks and in places abundant sulphides.
 - c. Major Mines. About one-half of these veins are of this type. Some are mainly quartz and free gold, and some show quartz bands with horses of country rock between.
 - d. Emerald Creek. Much oxidized veins with large amount of manganese and iron. One vein is said to be 15 meters wide at the lowest point.
 - e. Batwaan. Veins from 1 to 1.5 meters in width with hard bluish quartz as gangue. Sulphides abundant. Some galena present.
 - f. Madison. Brecciated quartz with manganese. Vein varies in width from 1 to 5 meters.
 - g. Antamok. Several quartz veins, granular and loose near the surface.
 - h. Inca. Very wide quartz vein, a stringer of calcite.

3. Silicified vein matter and mineralized wall rock with galena, iron, free gold, and in some cases manganese:
 - a. Consolidated. A good strong lead with much mineralized walls, and silicious vein matter, more or less banded and partially crystalline. High values for about 6 meters on foot and hanging walls in quartz with some manganese.
 - b. Fianza. Continuation of the "Consolidated" vein.
 - c. Major Mines. Showing frozen walls and much mineralized country rock in a few cases.
4. Quartz with copper and free gold; also galena and zinc in some cases:
 - a. Union Jack, Camp Four. One sugar quartz lead and one massive quartz with high values in copper and free gold. All much oxidized and enriched. Both narrow and poor in depth.
 - b. Copper King. Some free gold with a considerable amount of copper and manganese.
 - c. Major Mines. One lead contains a stringer rich in gold, galena, pyrite, and copper.
5. Quartz with no free gold:
 - a. Kelley (north slope). Four veins occur, 1 to 5 meters wide, containing tellurides of gold with pyrites, or ores of gold of the telluride type.
6. Quartz with free gold and cinnabar:
 - a. Ascension group. A lead on the Kias trail, much oxidized, contains beautiful blood-red crystals of cinnabar the size of fine sand.
 - b. Batwaan. One quartz lead 1 to 1.5 meters wide.
7. Quartz with wire gold or plate gold (rare):
 - a. Major Mines. One vein occurs in which free gold is visible in the ore.
 - b. Madison Group. Plate gold found in crystalline quartz stringer in the country rock. (F. T. E.)

MINERALS IN THE BENGUET LODES.

The following minerals have been found in the various Benguet leads. A few of their characteristics as they occur in the district are given with each.

QUARTZ (SiO_2).

Milk-white, bluish-white almost opaline and in clear-cut hexagonal crystals in druses in the ores, sometimes cellular showing leaching. It is the gangue mineral in the majority of veins.

CALCITE (CaCO_3).

Milk-white often associated with rhodochrosite; also in stringers in quartz veins.

RHODOCHROSITE (MnCO_3).

A pinkish massive mineral in certain calcite veins.

PYROLUSITE (MnO_2).

Soft black masses filling pockets and crevices, or as dirty, black incrustations, and as bands in the calcite.

KAOLINITE ($H_4Al_2Si_2O_9$).

Probably not pure, occurs as part of the clay gouge next to the vein walls.

TALC ($H_2Mg_3(SiO_3)_4$).

Mixed with kaolin as an amorphous mass.

LIMONITE ($2Fe_2O_3 \cdot 3H_2O$).

This is found as a yellowish stain in the veins in the oxidized zone. It is a result of the alteration of the pyrite in part and the decomposition of ferruginous wall rocks.

HEMATITE (Fe_2O_3).

This is a reddish incrustation originating in the same manner as the limonite; it also occurs as small, hard, bluish-gray flakes and particles which remain in the pan when panning for gold.

PYRITES (FeS_2).

This mineral is intimately associated with the gold, often enclosing minute gold particles. Occurs universally in the veins and also in the country rock.

GALENA (PbS).

This lead-gray, heavy mineral with its characteristic cubical cleavage, yielding silvery bright faces, has been found in small quantities only, associated with a small amount of sphalerite and chalcocite in a few veins in Gold Creek.

CHALCOCITE (Cu_2S).

This mineral occurs both in the massive form and as slender orthorhombic crystals in several places in the veins on the Kelley property.

MALACHITE ($CuCO_3 \cdot Cu(OH)_2$).

Occurs as occasional bright green incrustations in the Gold Creek lodes.

CHALCOPYRITE ($CuFeS_2$).

Only occasionally seen and usually as small, irregular, and amorphous pieces.

CHROMITE ($FeCr_2O_4$).

Found in some of the Major Creek lodes as small botryoidal masses; black, with a sublustrous to dull appearance.

SIDERITE ($FeCO_3$).

Found in some lodes in the lower Antamok in compact and earthy fragments. Color brown. Not very prominent.

MAGNETITE (Fe_3O_4).

Occurs as small grains in many of the ores.

ILMENITE ($FeTiO_3$).

Occurs with magnetite.

OLIVINE ($Mg \cdot Fe_2SiO_4$).

Probably derived from some decomposed basaltic inclusion in the vein.

EPIDOTE ($\text{HCa}_2(\text{Al} \cdot \text{Fe})_3\text{Si}_3\text{O}_{13}$).

A yellowish to pistachio-green mineral, occurring as does olivine.

CINNABAR (Hg_2S).

This mineral has been found in two places in the quartz veins on the headwaters of Major Creek and Batwaan Creek. It occurs in very small, almost minute, bright red crystals which are left in the concentrates in the gold pan. When examined with a magnifying glass the rhombohedral crystals can be distinguished.

SILVER (Ag).

We have never seen any free silver from this district, although there is an appreciable amount alloyed with the gold.

TELLURIDES.

Undoubtedly some of the tellurides exist in these ores, although we have not been able to isolate sufficiently large fragments to determine what telluride is present. The wet test for tellurium has been obtained twice and many samples of ore on roasting show the gold "sweated out." We have found such samples only on the Kelley property, coming from small pockets.

GOLD (Au).

The gold in this region usually occurs as microscopic particles disseminated through the quartz and pyrite. Occasionally, specimens with visible gold are found, but they are rare. The largest piece we have seen from the district was found on the ridge on the western side of the Antamok River on the Madison property. It consisted of thin plates or scales of gold in a quartz stringer. The gold wherever found in this district, is much lighter in color than usually is the case. This is due to the alloy with more or less silver. (W. D. S.)

HOT SPRINGS.

Only a few hot springs are located in the part of the district under discussion in the present paper, and one of these is a little south of the lower limit of the map.

The Itogon hot spring (see large map) is situated on the south bank of the Batwaan, on a bench a few feet above the water. It has deposited a considerable quantity of travertine around the vent. The water is boiling hot. This spring is on the strike of a small vein which has calcite for a gangue. Pannings of this calcite gave "colors." Analysis of this water can not be given at this time, as the only sample collected was lost.

KLONDIKE HOT SPRING.

A hot sulphur spring issues from a small fissure in the conglomerate formation, about 3 kilometers above Camp One on the Benguet Road and on the west bank of the Bued River. An analysis is as follows:⁶

⁶ Analysis by V. Q. Gana, laboratory of physical and inorganic chemistry, Bureau of Science.

Constituent.	Parts in a million.
Silica (SiO_2)	40.9
Sulphuric acid radicle SO_4	348.6
Bicarbonic acid radicle HCO_3	21.3
Carbonic acid radicle	Nil.
Phosphoric acid radicle	Trace.
Chlorine	588.0
Iron and aluminum	Trace.
Manganese	Nil.
Calcium	134.0
Magnesium	Trace.
Potassium	Trace.
Sodium (Na)	388.2
Free CO_2	2.2

ORIGIN OF THE ORE VEINS AND DEPOSITS.

Any discussion of the origin of the ore deposits in this region may seem to many to consist largely of theory and speculation. However, we believe it can be shown that many facts are known about them and that a broad discussion of these facts will reveal some very practical conclusions. As no mine in the district has gone below water level, the reason for the frequent use of the word "probable" will be understood. Given certain conditions and knowing the results arising from those conditions in other parts of the world, we can in some measure understand the past and conjecture as to the future.

The following facts seem fairly well to be established in regard to the ore deposits of this district:

- (1) They are intimately related to igneous intrusion.
- (2) Gold is found in quartz fissure-veins, in andesitic intrusives.
- (3) It is found in calcite veins, in andesitic intrusives, and in diorite.
- (4) The metal is encountered in contact zones between sediments and andesitic intrusives, and between andesites and diorites.
- (5) Gold was deposited from ascending waters.
- (6) It was precipitated by ferrous sulphate and in one locality probably by compounds of tellurium.
- (7) The gold veins in many cases carry oxides of manganese.
- (8) The gold content is as a rule less than 30 per cent free milling.
- (9) There has been considerable secondary enrichment.
- (10) The ore deposits are found in a region of great precipitation and steep slopes.
- (11) The zone of oxidation is shallow.

The principal veins in the district follow fractures in the igneous intrusions and contacts with igneous intrusives, and the metallic contents in the writer's opinion were derived originally from minute and widely disseminated particles throughout the igneous rocks. Underground water was the agent in this work. This water was very silicious and probably hot.

This period of ore deposition was not very long ago, as is attested by the presence of very recent deposits which carry appreciable gold values, originating from springs and which are found now on the surface in this region. A large deposit of silicious sinter has been cut through on

the "Military Cut-off" Road near Government Center. Samples from this location were assayed by Mr. Durrell, formerly superintendent of the Headquarters Mining Company, and found to carry from 1.80 pesos to 2.80 pesos in gold per ton. Mr. Hulbert of the Major Mining Co. reports "colors" from pannings of material in a small quartz and calcite lead about 20 meters from the hot spring at Itogon. This spring is located on the strike of this vein.

We find three distinct modes of the occurrence of gold. In the Gold Creek-Batwaan system the metal is present in quartz veins with small amounts of cinnabar, tellurium, galena, several copper minerals, chromite and others, but with practically no manganese. In the upper part of Antamok we find gold quartz veins with a subordinate amount of calcite but a large amount of manganese oxide. In the lower parts of Antamok Creek the gold occurs in calcite veins with heavy oxide. The manganese is also encountered in the form of the carbonate, rhodochrosite.

Such differences are due to a variation in the rocks through which the underground water traveled and the minerals which it dissolved before it reached the trunk channels and precipitated its solute. The following facts seem to give fairly conclusive evidence that the gold was deposited in general from ascending waters: (1) The relation of the deposited gold to recent spring deposits was shown above; (2) the presence of richer values of primary ore beneath and close to the hanging wall in some veins.

The veins in this district are similar in many respects to those of California and parts of Australia. Pyrite is the dominant sulphide in the ore. The gold solution at first probably decomposed the pyrite and produced a salt of iron which in turn precipitated the gold. Ferrous sulphate formed by oxidizing waters acting on pyrite, as well as compounds of tellurium, are known to be precipitants of gold.

The occurrence of manganese in gold veins has been shown to be of great importance in other parts of the world. Recently, Emmons has published two rather complete expositions of the subject,⁷ setting forth the results of both laboratory and field work. Ferguson of the Bureau of Science, in an article on the Geology and Mineral Resources of the Aroroy District, Masbate,⁸ has shown the application of these results to that field. The following is a quotation from Emmons' Paper:

Ferric iron, cupric copper, and manganitic manganese are present in many mineral waters, and under certain conditions any one of them will liberate chlorine from sodium chloride in acid solutions. Nascent chlorine dissolves gold. Each of these compounds releases chlorine at high temperatures, or in concentrated solutions. In cold, dilute, acid chloride solutions, ferric iron will not give nascent chlorine in appreciable quantity in 34 days, and cupric copper is probably even

⁷ *Am. Inst. Min. Eng. Bull.* (1910), 768; *Journ. Geol.* Chicago (1911), 19, 15.

⁸ *This Journal, Sec. A* (1911), 6, 397.

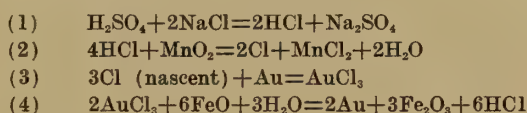
less efficient, but manganitic compounds liberate chlorine very readily. In a cold solution containing only 1,418 parts of chlorine per million, considerable gold is dissolved in 14 days when manganese is present. It should be expected, then, that those auriferous deposits, the gangues of which contain manganese, would show the effects of the solution and migration of gold more clearly than non-manganiferous ores.

Gold thus dissolved is quickly precipitated by ferrous sulphate. It is, therefore, natural to suppose that gold in such solutions could not migrate far through rocks containing pyrite, since it would be precipitated by the ferrous sulphate produced through the action of oxidizing waters, or the gold solution itself, upon the pyrite. But the dioxide and higher oxides of manganese react immediately upon ferrous sulphate, converting it to ferric sulphate, which is not a precipitant of gold. Consequently, manganese is not only favorable to the solution of gold in cold, dilute mineral waters, but it also inhibits the precipitating action of ferrous salts, and thus permits the gold to travel farther before final deposition.

These statements apply to the action of surface waters descending through the upper parts of an auriferous ore deposit, since such waters are cold, dilute, acid (i. e., oxidizing) solutions. In deeper zones, where they attack other minerals, they lose acidity, until the manganese compounds, stable under oxidizing conditions, are precipitated together with the gold. Thus, manganite, as well as limonite and kaolin, is frequently found in secondary (i. e., dissolved and reprecipitated) gold ores. Moreover, in the precipitation of secondary copper and silver sulphides, ferrous sulphate is generally formed; and, consequently, the secondary silver or copper sulphides frequently contain gold.

Those deposits in the United States in which a secondary enrichment in gold is believed to have taken place are, almost without exception, manganiferous. Since secondary enrichment is produced by the downward migration, instead of the superficial removal and accumulation, of the gold, it should follow that both gold placers and outcrops rich in gold would be found more extensively in connection with non-manganiferous deposits; and this inference is believed to be confirmed by field-observations.

For the sake of brevity the process outlined above, can be represented by a series of equations as follows:



Those are the simplest reactions which take place. However, there are others which we shall not discuss here; they may be found in the literature on the subject.

It is well known that the chlorination process was formerly very generally used for the extraction of gold, and still is for certain classes of ore. Analyses have shown repeatedly, that chlorine is generally present in mine waters and in fact most underground waters. Even water from very close to the surface has a small amount. An analysis of mine water from one of the upper tunnels (close to the surface) of the Headwaters mine showed some chlorine. Given plenty of time even a small amount of chlorine will take care of the comparatively

small amount of gold in the veins. There is reason to believe, also, that in certain parts of the Benguet region there is a great deal of chlorine present in the underground water because of the salt springs which exist there. Note, for instance, the amount of sodium chloride in the analysis of the Klondike Spring, on page 439.

We can feel sure then, that we have the proper conditions for the reactions outlined above.

The above discussion in so far as it relates to the Benguet regions, can be summed up in the following conclusion:

We can reasonably expect to find the gold values increasing with depth in the veins carrying manganese, though exceptions to this are known. (W. D. S.)

OXIDIZED AND SULPHIDE ZONES.

Inasmuch as no mine in Benguet as yet has gone below the zone of enrichment, what will be found in the sulphide zone can not be foretold. Some of the prospects are at present in the semi-leached zones and some in the zone of enrichment. In both these cases the ore appears to be very good, but no information is available as to its condition in depth. In one case, a vein, strong on the surface, pinched out almost completely within a depth of 30 meters. In another, the good values seemed to lead in depth into the adjoining property, yet on the other hand, the Muyot has been developed to a depth of over 100 meters below the highest point in the outcrop and appears to be as strong below as it was near the surface. It is opened by adits only, so that it scarcely can be taken as an example of ore at depth, although the ore generally seems to be primary. Another case is supplied by an ore vein in Emerald Creek. At the highest exposed point the vein is only 1 meter wide, but 33 meters lower and about 1 kilometer distant, it has reached a width reported to be over 13 meters, still in a wholly oxidized, semi-leached condition. These conditions point to ore bodies in depth, but they may or may not be rich enough to work. Telluride ore has been found by one prospector, which although formerly accepted as pointing to ore in depth, might be secondary in its formation. Generally the values in the veins are greatest next to one or both of the walls; and in the majority of cases it is apparent that this characteristic is due to secondary enrichment by descending waters. (F. T. E.)

ECONOMIC GEOLOGY.

In the bulletin, Mineral Resources of the Philippines, will be found each year a statement of the gold production of this district, with more or less discussion about each property, and in the 1912 bulletin a fairly complete description of them will appear. Suffice it to say in this place that there are about 25 gold properties; on four of them mills are now running or have been until recently.

In 1910 the total production of the district amounted to 95,960 pesos including a small amount won by the natives in the northern part of the Province.

NONMETALLIC MINERALS AND STRUCTURAL MATERIALS AND THEIR
ECONOMIC POSSIBILITIES.

Limestone.—The gold fever has been so acute in this district that very little attention has been given to the nonmetallic minerals available. Our survey of the vicinity of Baguio has shown that good limestone

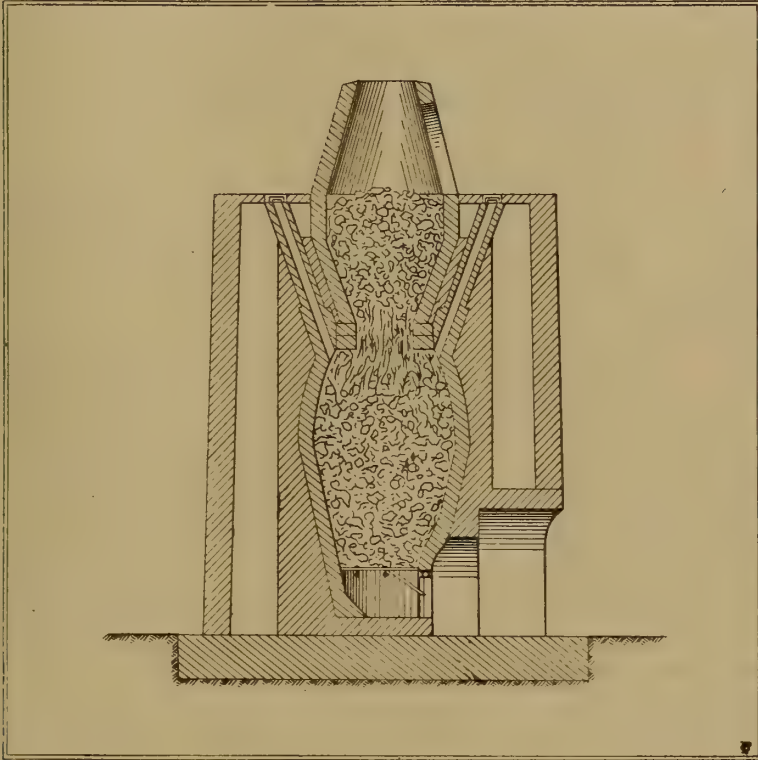


FIG. 2.—Aalborg kiln for lime burning.

for building stone exists. It has been used in the Jesuit Observatory located on Mount Mirador and promises to be very desirable. This rock, also, on account of its comparative purity makes a very fine grade of lime. There is more or less recrystallized calcium carbonate in it which makes it all the more desirable for this purpose.

The Jesuit fathers burned their lime in an ordinary dome-shaped kiln, using limestone blocks. A better kiln for continuous work is that given in the cut. (Fig. 2.) Favorable spots where lime might be burned are indicated on the large map.

Silica.—At one place on the Military Cut-off there is a deposit of loose siliceous sinter which could be used in the making of sand-lime brick, for pottery glazing, or for glass.

Sand-lime brick.—Recently a large sample of the soft siliceous sinter from the "Military Cut-off" road was sent to W. C. Reibling of the chemical laboratory, Bureau of Science, who mixed it with lime and made the material into sand-lime bricks. Although the work as yet is only preliminary, he has obtained encouraging results.

Mr. Reibling's work shows the possibility of the manufacture of good bricks in Baguio, of these materials, and also the possibility of using Portland cement with greater economy on the Benguet road. Although some Tarlac sand was used in making these briquets there was no need of it as the Baguio sinter is practically nothing but silica (94 per cent). Wherever a fairly pure sand and lime are available this process can be used.

Glass sand and pottery glazing.—There is the possibility of using this sinter for two other purposes, namely, for glass and for pottery glaze. The present high price of glassware in the Philippines, particularly window-pane glass, would seem to indicate a profitable undertaking in this direction.

Brick clay.—A good clay for making common red brick exists at several points. The best locality is in Trinidad Valley. Another is in the hollow just below the Hotel Pines, but as this tract will be used as a park it will be out of the question for this purpose. A pit deeper than the present stream level will be needed to secure the clay in Trinidad Valley, as the material above this level carries too much gravel. One sample which we procured from the bottom of the large stream not far from the south end of the valley is grayish yellow and very plastic. When tested by Alvin J. Cox of the laboratory of inorganic chemistry, of the Bureau of Science, very satisfactory results were obtained, showing that there is, of a certainty, materials available for the manufacture of clay bricks in addition to sand-lime bricks.

It may at once be argued that brick construction is not quite suited to an earthquake country. As opposed to this idea, we can cite the experience in San Francisco. It is the opinion of more than one contractor, that a reinforced-concrete structure is apt to be permanently warped during an earthquake, and hence *not* the best type of construction. This is not the case with bricks on a steel frame.

Road metal.—For several reasons I have reserved the discussion of this heading for a future article. A number of abrasion and cementation tests have been completed on a variety of rocks from this region.

SUMMARY.

1. The rocks of this region comprise sedimentaries, volcanic breccias, metamorphic rocks, intrusive and extrusive igneous rocks of Tertiary and possibly Mesozoic age.

2. The principal rock is andesite, a lower and an upper formation separated by sedimentaries.

3. The gold veins are largely fissure veins in the lower intrusive andesite.

4. This lower andesite grades imperceptibly into diorite.

5. This is a region of steep slopes and excessive rainfall (38 inches fell in 24 hours on the 15th day of July, 1911, in Baguio).

6. By reason of this excessive rainfall, steep slopes and the geologic conditions of the andesite on the upper slopes of the Benguet cañons the building of highways along the bottoms of the gorges has involved, and, until these slopes are reduced to a lower angle, will involve great engineering risks.

7. Gold is the principal mineral of economic value.

8. The ores for the most part require the cyanide process.

9. There are 25 stamps in the district, distributed through 4 mills.

10. There is only 1 cyanide plant in operation.

11. Manganese is secondary in the veins and is characteristic of the district as a whole.

12. The values are very irregularly distributed in the ore bodies.

13. No mine has yet gone below water level.

14. The gold production for 1910 amounted to 95,960 pesos.

15. There are noteworthy ore bodies here but for the most part they are not developed.

16. Consolidation of properties would be advisable.

17. Better power facilities are needed.

18. The timber question will shortly be a serious one.

19. Capital is badly needed.

20. Materials for making lime, sand-lime, and clay bricks, for glass and pottery glaze are available in the district.

21. The production of nonmetallics has been negligible.

22. Good road materials exist in this region.

23. Limestone is particularly good for this purpose on account of its high cementation property, but the best material so far found is a diorite containing secondary calcite as a result of incipient decomposition.

ILLUSTRATIONS.

PLATE I.

Metamorphosed porphyritic rock, showing outlines of feldspars which have been replaced by secondary silica. (Photomicrograph by Martin.)

PLATE II.

Characteristic topography in the Benguet district. (Photograph by Photo Supply Co.)

PLATE III.

Geologic cross-section along the line A-B of the geologic map.

MAP.

Geologic map of the Benguet mining region.

TEXT FIGURES.

FIG. 1. Ideal section through the Benguet region east and west.

2. Aalborg kiln for lime burning.

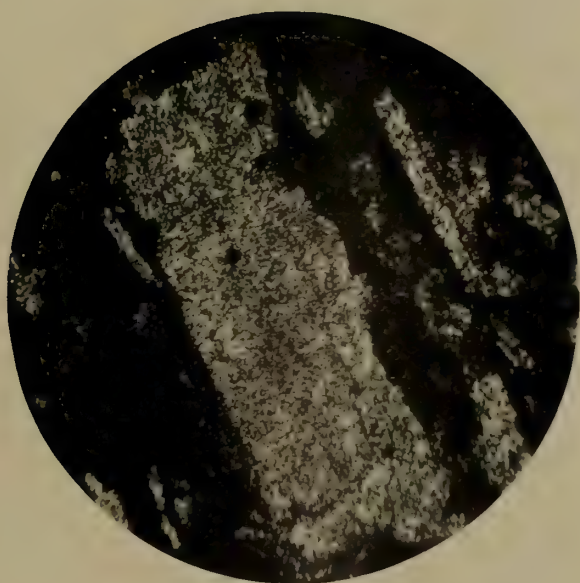
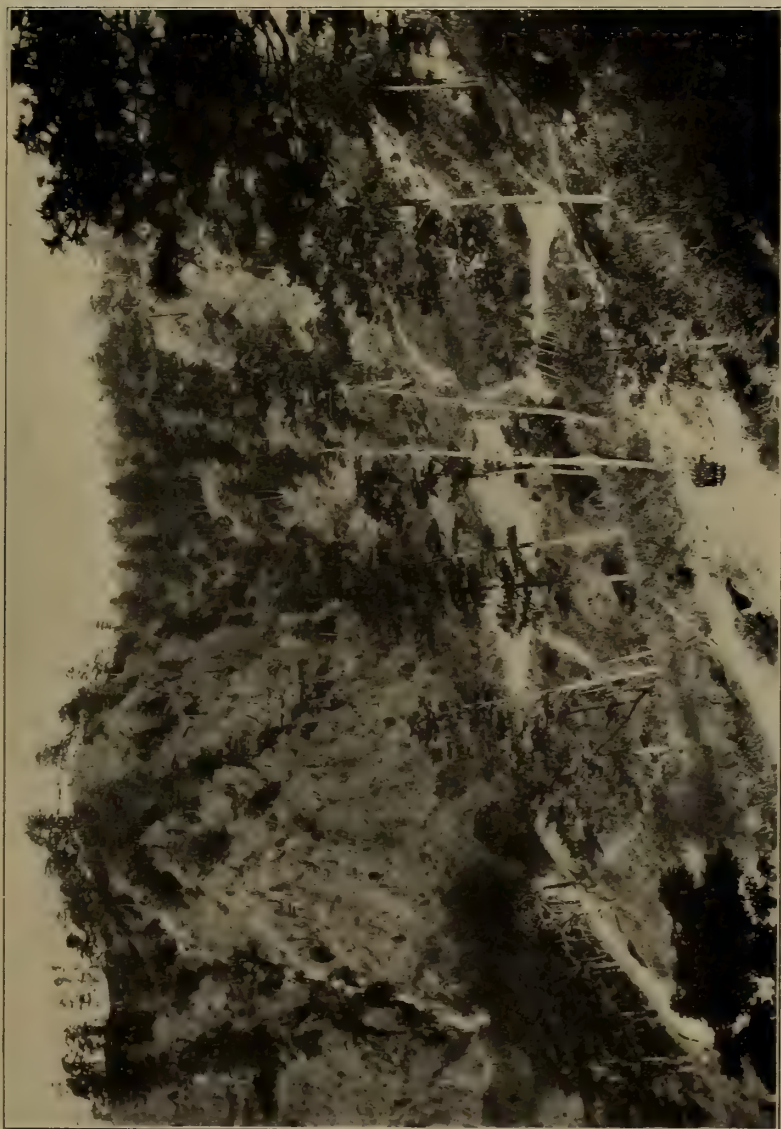


PLATE I.



Courtesy of Photo Supply Co.

PLATE II.



1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0

A.

B.

Vertical Scale 1 cm. 200 meters

ACTUAL SECTION ALONG LINE A. B.

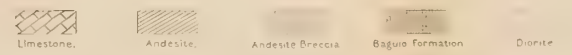


PLATE III.
GEOLOGIC CROSS-SECTION ALONG THE LINE A-B OF THE GEOLOGIC MAP.

GEOLOGIC RECONNAISSANCE OF SOUTHEASTERN LUZON.

By GEORGE I. ADAMS and WALLACE E. PRATT.

(From the Division of Mines, Bureau of Science, Manila, P. I.)

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INTRODUCTION.

This reconnaissance continues geographically the study of the geology of the Island of Luzon from the southwestern portion, concerning which a report has been published,¹ to the southeastern extremity. These two areas are indicated on the index map as shown in text figure 1. The physiographic and geologic divisions are distinct, with the exception of portions of the Eastern Cordillera which occupy a part of each area arbitrarily limited for convenience in mapping. Both divisions of the Island contain volcanic features which are of especial interest. In southwestern Luzon there are some isolated volcanic peaks, crater lakes, cinder cones, and the Volcano Taal. Southeastern Luzon contains a notable range of volcanic peaks, including the exceptionally symmetrical and perfect cone of Mayon.

These two parts of Luzon with their minor features form an epitome of the geology of the Islands. Von Drasche made a partial reconnaissance of these areas. It was hoped that the present report would complete a systematic reconnaissance, but the time for field work, which was limited to the months of April, May, and June, precluded such a result, although it permitted the study of the greater part of the area. Previously, a reconnaissance of the Tayabas oil field had been made and the results which

¹ *This Journal, Sec. A* (1910), 5, 57.



FIG. 1.—Index map showing physiographic regions of Luzon.

were published in a press bulletin are incorporated in this paper. Caramuan Peninsula and most of the northern part of the cordillera, including Mounts Labo and Cadig, are practically uninhabited and very little is known of their interior geography. Only meager information was gained concerning the geologic constitution.

The new, accurate charts by the Coast and Geodetic Survey show many modifications of the position and details of the coast as given on the old maps. The geography of the interior is best known from the unpublished maps by d'Almonte, which in places are only sketches.

The economic geology of the area centers in the coal mines on Batan Island, which have been studied by Smith, the Paracale-Mambulao mining district, which is producing and has been the subject of several short reports, the Nalasvetan mining camp which is new, the prospects on the head of Ragay Gulf, and the Tayabas oil fields, where drilling is now in progress. On Catanduanes Island prospecting for gold is being carried on and coal has also been found. Coal is likewise known to exist on Rapu-Rapu Island and at a number of places on the mainland, but it is not now being mined, except on Batan Island.

PHYSIOGRAPHY.

The dominant physiographic feature of southeastern Luzon is a chain of volcanic peaks extending in a northwest-southeast direction and here named the Southeastern Cordillera.² (See figs. 1 and 2).

Caramuan Peninsula, and Catanduanes Island which seems to be related to this peninsula, form a province which diverges from the central portion of the cordillera. Farther south the Batan chain of small islands, including San Miguel, Cacaray, Batan, and Rapu-Rapu Islands, lies nearly parallel to the cordillera. The Ragay Coast Hills are on the western flank of the chain of volcanic peaks. The northern and southern parts of this province border the Southeastern Cordillera, but its central portion is separated from the latter by the Bicol Valley. Bondoc Peninsula, or Tayabas Peninsula as it is sometimes called, and the isthmian portions of Luzon to the north of it, are a continuation of the Eastern Cordillera.

Alabat Island is related to this region. Between the Eastern and Southeastern Cordilleras and extending from Ragay Gulf to Basiad and Calauag Bays, there is an area of slight relief which is here called the

² On the index map of the physiographic regions accompanying the report on southwestern Luzon (*loc. cit.*) the Southeastern Cordillera was shown as extending into Caramuan Peninsula, and a southeastern volcanic region was noted. This erroneous interpretation was based on the hachuring seen on published maps.

Viñas Lowland from the name of its principal river. These physiographic divisions are shown in text figure 2.



FIG. 2.—Physiographic divisions of southeastern Luzon.

Southeastern Cordillera.—This mountain range is broken into three parts by San Miguel and Sorsogon Bays. The northern portion is broad and, in addition to many features of moderate relief, contains three conspicuous mountainous areas. In the Cadig Mountains at the north there is a peak which, according to the Coast and Geodetic Survey charts, is 702 meters in height. As seen from a distance this group presents no salient features. To the south of it, and separated by a long gap, is the Labo group of peaks which is dominated by Mount Labo, having the appearance of a volcanic cone and rising to an elevation of 943 meters; Mount Bayabas, just to the northeast, has an elevation of 433 meters. There are two conspicuous spurs in this group, one extending to the west and the other to the south. The Colasi group is separated from the Labo Mountains by a gap. A number of its highest peaks stand near the shore of San Miguel Bay. Some of the peaks may be of volcanic origin, but there is no dominant volcanic cone. The highest determined elevation reaches 750 meters. Colasi Peak, which rises from the shore, has an elevation of 389 meters. This mountain is a noted landmark. Jagor has published a profile of it as seen from Lalanigan, a *barrio* to the southeast, and this shows it with a subconical form. A more interesting view is obtained when passing the mountain on a steamship.

The sea has cut away a portion of its base and erosion has developed the following features on the seaward side. The central portion has the form of a partially uncovered cone, suggesting a volcanic plug or neck. On each side of this central cone there is a lower, shoulder-like mass. Two rather symmetrical gulches are developed between the shoulders and the cone and approach each other as they descend to the sea. The view of the peak from the north shows the shoulders to be connected behind the central cone by a ridge, and from this ridge there is a gradual slope inland. This feature is also shown by Jagor in his sketch of the peak as seen from Colasi.

Mount Bagacay, or the Sierra de Bagacay of former writers, remains to be mentioned as a prominent topographic feature. This elongated ridge has an elevation of about 900 meters and lies near the coast between Daet and Paracale. It is separated from the cordillera proper by the valley of the Labo River. It does not belong to the chain of volcanic peaks, but probably is an older feature the relations of which will be discussed in dealing with the geology of the region.

Between the northern and central division of the cordillera there is a wide gap occupied by San Miguel Bay and the lowlands at the mouth of the Bicol Valley.

Isarog, an extinct volcano, is the first peak in the central division. As its name in the Bicol language implies, it stands alone. Its base occupies a large area; its lower slopes rise gradually, and their symmetry is not impaired by subsidiary cones, but on the northwest flank there is some broken country dissected by deep ravines. As seen from the west, Isarog is dome-shaped. Moreover, from the east the summit is seen to be formed by a crescent-shaped ridge, and the great crater, which is drained by the Rungus River, may be observed through a deep cleft. A point on the north part of the crater rim has an elevation of 1,979 meters, and one on the south an elevation of 1,908 meters.

Roth and von Drasche cite Hochstetter's explanation that Caramuan Peninsula, which at one time was probably an island, has been joined to the mainland by the eruption of Isarog.

Mount Iriga, elevation 1,196 meters, is a volcanic peak. Jagor writes as follows concerning it:

"I was informed by the priests of the neighboring hamlets that the volcano until the commencement of the seventeenth century had been completely conical and that the lake (Buhi) did not come into existence until half the mountain fell in at the time of its great eruption. This statement I found confirmed in the pages of the 'Estado Geográfico.' On the fourth of January, 1641, a memorable day,—for on that day all the known volcanoes of the archipelago began to erupt at the same hour,—a lofty hill in Camarines inhabited by heathens fell in, and a fine lake sprang into existence upon its site. The then inhabitants of the village of Buhi migrated to the shores of the new lake, which, on this account, was henceforward called the lake of Buhi."

Von Drasche, who visited Iriga, described the crater as being filled with chaotic masses to half the height of the north wall and to contain a deep hole called the "well." He refers to the legend of the falling in of Iriga and says that the great blocks of stone which one sees near Buhi Lake and strewn farther out give a presumptive proof.

What actually happened at the time of the formation of Buhi Lake and the so-called eruption or sinking of a part of Iriga probably will never be entirely clear. The topography suggests that a section of the cone broke down and was thrown outward to the south, and that the debris formed a dam which gave rise to the lake. On published maps, Buhi Lake is shown without an outlet, but there is a river which flows from it in small falls and rapids across the debris of the supposed eruptions.

A group of lower peaks, probably eruptives, rises from the coast between Iriga and Lagonoy Gulf. They may be called the Elizardo Mountains from the name of the principal peak, which has an elevation of 666 meters. These mountains have the appearance of a spur from Mount Malinao.

Mount Malinao is volcanic. It contains a great crater which may be seen from the east by looking up the deep gulch through which its interior is drained. Its inner walls are bare and show recent rock falls. The sky line of the summit is nearly horizontal and the rim of the crater is crescentic. The elevation on the north summit is 1,547 meters and on the south, 1,657 meters.

Mount Masaraga is somewhat pyramidal as seen from the south and has no crater but is usually considered a volcanic peak. The elevation is 1,339 meters. A long spur extends from its peak to the northwest.

Mayon Volcano rises from a broad base to an elevation of 2,421 meters. The mountain is remarkably symmetrical and is considered one of the most perfect cones in the world. The western side of the rim of the small crater in its apex is higher than the eastern. The outline of its summit is gradually being roughened by weathering and erosion and its flanks are marked by deep grooves, but these details, when seen from certain directions and viewed from a distance are softened and the beauty of the cone is most impressive. Only a cone the summit of which is terminated by a snow cap, can rival Mayon for symmetry. There are no craters or parasitic cones on the slope of the volcano. To the northeast, near its base, there are some eruptive hills, one of which has an elevation of 457 meters. Just north of Albay there is a small cone having an elevation of 169 meters.

The panorama of volcanic peaks extending from Isarog on the north to Mayon on the south may be seen from steamships passing on Lagonoy Gulf. Similarly, the traveler who journeys by land from Legaspi to Nueva Caceres through the Bicol Valley may obtain a comprehensive

view from the vicinity of Bato Lake. Isarog has the largest base of any of the peaks and was once a high volcano. It has suffered erosion to a great extent. Mayon, on the south, retains its nearly perfect form. The volcanic nature of the central portion of the range is more apparent when it is seen from the east, whence the crater of Malinao is visible.

The Gulf of Albay partially interrupts the continuity of the cordillera to the south of Mayon. The next group of peaks, which are here called the Pocdol Mountains, occupies the country between Albay Gulf and Sorsogon Bay. The elevations of some of the highest points which are situated in the eastern part of the area are 1,099, 1,037, 1,027, and 966 meters, and there are a number of others which approach these altitudes. Certain of the peaks appear to be of volcanic origin, but there are no distinct cones. This mountainous area descends rather abruptly toward Albay Gulf, but to the westward has a long slope.

The third division of the Southeastern Cordillera is situated in the peninsula area which constitutes the larger part of Sorsogon Province. It is dominated by Bulusan Volcano, the cone of which has an elevation of 1,556 meters. A sharp peak to the northeast, which is a part of Bulusan, reaches 1,215 meters. The north and east slopes of the volcano descend quite regularly toward the isthmus and the sea. The country is broken to the south. Mount Jormajan, elevation 726 meters, lies west of Bulusan and apart from it. A number of lower mountains, including Mount Bulacan, elevation 860 meters, and Mount Calomutan, elevation 617 meters, form a broken ridge lying to the west of the volcano and have the same trend as the cordillera. A low continuation of this ridge is found north of the entrance of Sorsogon Bay.

Jagor has written:

"Bulusan is surprisingly like Vesuvius in outline. Like its prototype it has two peaks. The western one, a bell-shaped summit, is the eruption cone. The eastern apex is a tall rugged mound, probably the remains of a huge crater. As in Vesuvius, the present crater is in the center of the extinct cone."

Jagor saw the volcano only from the sea. A closer inspection shows that it is not so similar to Vesuvius as he has stated. The cone is not in the center of an extinct crater, but has been built on the western rim of an irregularly truncated peak. On the west, the slopes of the cone blend with those of the older part of the mountain. A depression is found between the cone and the sharp peak which Jagor thought to be the remnant of an outer crater.

Mr. Bloomfield, teacher of agriculture in the provincial school of Sorsogon, ascended the cone. He states that the crater in the summit is about 300 meters in diameter and 50 meters deep. It contains some sulphur deposits. On the western and northwestern inner slopes of the rim there are two vents in which there is slight solfataric action. On the outer, southeastern slope there are three vents or small craters. The highest one is dry. The lower two, which are about 75 meters in diameter, contain water.

Caramuan Peninsula.—Caramuan Peninsula has a very irregular north-east coast line which is bordered by a number of islands. The topography suggests that it has been "drowned," and the soundings near the shore indicate a submarine shelf. The 30-fathom line runs from the point of Catanduanes Island well off the shore of Caramuan and outside of the Calagua Islands. The northwestern part of the peninsula is low, the higher elevations rising from 85 to 200 meters. In the southern portion there are some conspicuous peaks which have elevations of from 425 to 900 meters, and Saddle Peak, which is the dominant one, reaches 1,031 meters. The coast bordering on Lagonoy Gulf is precipitous in many places and the gulf contains deep water, the 500-fathom line coming close to the shore of the peninsula. The eastern end of the peninsula is relatively high and very irregular.

The line of the higher mountains of Catanduanes Island is seemingly a continuation of the structure in Caramuan Peninsula. In the southern part of the island there are elevations determined to be from 552 to 798 meters. The central portion of the island is high and broken, but its northern extremity is of lower relief.

Batan Island chain.—The small islands lying between Lagonoy and Albay Gulfs and separated from each other by narrow passages and straits appear to be genetically related. The elevations of these islands are of moderate relief; the highest point on San Miguel is 91 meters, on Cararay 380, on Batan 460, and on Rapu-Rapu 534 meters. The geologic constitution of the chain suggests that the islands probably are the exposed portions of a fault block lying on the eastern flank of the cordillera.

Ragay Coast Hills.—This elongated area borders Ragay Gulf and, continuing southeast along the coast of the mainland, contains but a few conspicuous topographic features. The elevations of the higher points have not been determined and are not known even approximately, since the Coast and Geodetic Survey charts have not been revised in this region. The surface features are softened by the dense growth of vegetation, but a number of conspicuous elevations may be seen, such as Mount Caburanan and Mount Bantuin. Mount Bantuin was described by von Drasche as having the form of a low despressed cone with gentle slope. He conjectured that it is certainly of volcanic origin. His description of its form was given from seeing it from Ragay. It is found to be a ridge-like mountain and with no features which suggest volcanic origin if studied from other points and especially if viewed close at hand. Mount Bernacci is a mesa-like mass which presents an even skyline when seen from Libmanan which lies nearly to the north of it. Viewed from the northwest or southeast, its summit shows a gentle decline to the northward. Its sides are precipitous in many places. Its configuration is readily understood when it is explained that it consists of slightly inclined sedimentary strata, some of which are of massive limestone. In fact,

the Ragay Coast Hills in general have escarpment features, and the small hills, somewhat conical in form which give their higher portions a broken appearance, are remnants of sedimentary beds which have been weathered and eroded away from the intervening areas. The northeastern border of the Ragay Coast Hills, in their central portion, descends to the Bicol Valley. An arm of this lowland extends through the Ragay Hills to the coast at Pasacao. This low pass has been noted both by Jagor and von Drasche, who state that it probably was once a seaway. It affords an easy route of communication from the country around Nueva Caceres to Ragay Gulf.

During Spanish times some work was done in cutting a canal to connect the head of the stream which enters the sea at Pasacao with a tributary of the Bicol River. This undertaking was abandoned because it was expensive, and it is doubtful if the facilities for transportation in small boats would ever justify the undertaking.

The northern termination of the Ragay Coast Hills blends with the slope of the cordillera; the southern, where it joins the cordillera, is marked by the contrast in topographic feature resulting from the erosion of sedimentary beds and igneous rocks.

Bicol Valley.—This area is lowland drained by the Bicol River. Its southern portion has swift-flowing streams, tributary to Bato Lake. The river is sluggish when it leaves this lake and is bordered by areas which are swampy and overflow during the flood season of the river. The shores of the lake are subject to overflow, and a considerable portion of its surface is covered with a growth of aquatic vegetation.

Where the Bicol River impinges on the Ragay Coast Hills at a point about half-way between Bato Lake and Nueva Caceres, there are some slight rapids. The channel deepens below this point. Nine and one-half feet (about 3 meters) of water, according to the Coast and Geodetic Survey chart, are found at the wharf in Nueva Caceres. The mouth of the river contains bars which are shifting, and the water near the shores of San Miguel Bay at the mouth of the valley is very shallow.

There are but few minor accidents in the topography of the Bicol Valley. It appears probable that Bato Lake and the rapids between it and Nueva Caceres owe their origin to differential elevation. The head of the Bicol Valley appears to have been aggraded by the detrital material from the slopes of Mayon Volcano. There is an area of lowland on the coast at Legaspi and bordering Albay Gulf. Between this lowland and the head of the Bicol Valley the lowest elevation of the divide is about 100 meters. It seems probable that there was once a seaway between San Miguel Bay and Albay Gulf, which has been closed by local eruptions, the growth of Mayon Volcano, and regional elevation.

Eastern Cordillera.—The isthmian and peninsular portions of Tayabas Province have a northwestern-southeastern structure. They are

a part of the Eastern Cordillera of Luzon and form its relatively low southern extension. Alabat Island is related to this region. The highest elevations reach 381 meters in Bondoc head and 378 in Macalayao Mountain. The country has a number of parallel ridges due to the differential erosion of the folded and faulted sedimentary beds. These structures have a northwesterly trend. There are no important longitudinal valleys developed between the ridges.

Viñas lowland.—This physiographic province has no very distinct limits. It is differentiated because of the fact that one may pass from the head of Ragay Gulf to Calauag or Basiad Bay by ascending the Viñas River in a *banca* and making a short portage of about two hours of foot-travel to the streams which flow northward. The topography of the area is largely disguised by the heavy growth of timber. In traveling over it some low ridges are seen and the strike of the formations is parallel with the ridges in the Eastern Cordillera and are a continuation of the same beds. Von Drasche emphasized this in his mapping and description, and stated that in a geologically recent time there was a strait which connected Lamon Bay with Ragay Gulf. However, this appears to be doubtful, since there are only alluvial deposits in the valleys and no recent marine formations exposed within the area.

Minor districts.—In addition, there are some minor physiographic districts which should be distinguished, namely, the Bulan coastal plain, the Sorsogon lowland, and the Gatbo upland.

The Bulan plain extends from near Magallanes to a point just north of Butag and is a narrow belt added to the mainland by the emergence of a littoral marine deposit consisting largely of volcanic tuff. A considerable portion of its coast has low, vertical sea cliffs in which the formation is exposed.

The name Sorsogon lowland is applied to the isthmus which lies to the east of Sorsogon Bay. It probably was once submerged and its slight relief may be due to marine erosion. Its surface is largely formed of volcanic materials, some of which, such as, for example, the conspicuous, white pumice, evidently have their origin in the eruptions of Bulusan.

The Gatbo upland is a remnant of the formerly extensive Tertiary beds which on the eastern slope of the cordillera have disappeared from the mainland either through subsidence or erosion. The formation is represented in the Batan Island chain. The Gatbo upland may once have been an island which has been joined to the mainland by the extension of the superficial deposits of the Sorsogon lowland and recent elevation. The surface of the upland slopes to the eastward, and on the western border it reaches an altitude of 212 meters.

The littoral deposits at the head of Albay Gulf, on Tobacco Bay, at

the head of Lagonoy Gulf, and on the shore between Daet and Bagacay Points, form lowlands which have been aggraded. The Daet lowland bears evidence of emergence, as has been noted by von Drasche, who described the raised coral beaches along its coast.

GEOLOGY.

SOUTHEASTERN CORDILLERA.

Geologic formation.—The portion of the northern division of the cordillera which includes the Labo and Colasi Mountains was mapped by von Drasche as andesites and on the borders of the andesites he showed two areas of andesite tuffs and two of breccias and pumice (Plate I). Roth determined as andesites the rocks from this area collected by Jagor. In the geologic map which accompanies the present report it has not been possible to distinguish the varieties of andesites, nor to show the extension of the tuffs and breccias. The fragmental volcanics are found at many places not seen by von Drasche, and are in such intimate relations with the massive rocks that they can not be differentiated without detailed field work.⁸ Some basalts were encountered, but the andesites predominate.

Von Drasche noted that between Ragay and Lupi a gray, porous, hornblende andesite overlies the Tertiary formations. To the west of Mambulao, Tertiary sedimentaries are present over a considerable area, the limits of which were not fully determined. There are intrusions of andesites in these beds and they have been much disturbed from the horizontal position in which they were deposited. Some float coal has been found on the Dumuguan River near Nalasvetan and this is evidence that the Tertiary beds are represented at the headwaters of the stream. Similarly, there is some coal to the east of Quilbay and Talcauyan near the head of Ragay Gulf and with it there are Tertiary sedimentaries. The cordillera between Ragay Gulf and Sogod Bay is bordered by Tertiary formations, which have been folded and faulted. The facts above noted justify the conclusion that a part of the volcanics and eruptives which form the cordillera are younger than the Tertiary of this region. The rocks near Paracale and Mambulao will be considered in discussing this mining district.

In the central division of the cordillera, Mount Isarog, which stands alone at the northern end, and the Pocdol Mountains, which form the southern part, contain principally andesites with which some basaltic rocks are associated. Isarog was mapped by von Drasche as andesite and it was so considered by Roth. The rocks of the Pocdol Mountains were not

⁸ The petrographic determinations of the collection of igneous rocks made during this reconnaissance were undertaken by Warren D. Smith, chief of the division of mines, Bureau of Science.

studied by them. Between Isarog and the Poedol Mountains the formation consists of basalts, some andesites, and intermediate varieties. Röth and von Drasche called these rocks dolerites. On the map accompanying this report the tuffs, breccias, and agglomerates are not differentiated.

Sedimentaries are found only in two small areas of this division of the cordillera. Along the road between Pili and Baao and to the south of the Pauili River there are some exposures of limestone and marls. This locality is in the western foothills of Mount Iriga. It was seen by von Drasche, who mapped it as younger coralline limestone. The beds are nearly horizontal and rest upon andesites at some places, but the exposures are not good. In our report these limestones are mapped as Tertiary. Some small outcrops of a similar nature were seen southeast of Bato, but they are too small to be shown on a reconnaissance map.

Some coal of poor quality was seen to the east of Mayon, in the *barrio* of Salvación which is in the jurisdiction of Libog. It occurs in a remnant of the Tertiary formation. These sedimentaries overlie a greenish, altered basalt found in the peninsula east of Libog and which is unlike the typical basalts of Mayon. The Tertiary at this place probably is related to the larger area found in the Batan Island chain.

The western limit of the central division of the cordillera is formed by the alluvial and brackish water deposits of the Bicol Valley, except to the south where the Tertiary is present on the border. The relation of the Tertiary sedimentaries to the rocks of this part of the cordillera was not satisfactorily determined, but they seem to lie unconformably upon the igneous rocks, and the basal beds contain conglomerates which appear to have been derived from the cordillera during an early stage of its growth.

The southern division of the cordillera, which includes Bulusan Volcano, is formed principally of basalts with which are associated some andesites. Röth classified the rocks which he saw from the area as dolerite. A large part is covered with tuffs, breccias, and agglomerates. Probably much of the tuff is from Bulusan, but no doubt there are other points from which fragmental materials were erupted. There is a fairly distinct range of smaller peaks which lies west of Bulusan and includes Culungan and Bintican. On the continuation of this line there is an area of basalts with andesites, north of the entrance to Sorsogon Bay.

No Tertiary sedimentaries were found south of Sorsogon Bay with the exception that east of Magallanes there is a bed of coal which has been opened. The roof of the coal has the nature of an agglomerate and, in so far as it was possible to determine, no extensive sedimentary beds are associated with it. The coal is of poor quality, and although it attains

a thickness of a little more than a meter, it probably can not be mined commercially.

It was reported that marble is found on the coast a short distance west of Matnog, but the place was not examined. It may be that there are some raised coral reefs in this vicinity. Limestone was reported as occurring near Castilla on the north shore of the entrance to Sorsogon Bay. An examination of the locality which is near the *barrio* of Libtong resulted in finding some raised coral beaches.

Formation of the Paracale-Mambulao mineral district.—Von Drasche mapped this district as older crystallines, gneiss, chlorite-hornblende-schist, etc.

Ickis, who described the district but did not attempt any mapping, stated that in a general way it may be said to consist of hornblende diorite, schist, and gneiss. He writes that Mount Bagacay is composed of diorite porphyry and that in the lower hills east of the Malaguit there is a light-colored hornblende diorite. He also referred to the gneissic and schistose texture of the rocks at various places. At the Tumbaga mine he found a rock having the appearance of a slate. He also mentions an andesite as occurring at this mine.

Smith in his report states that the formations found in the district are pyroxenites, schists, granite gneiss, granite, shale, sandstone, and andesite, from north to south in the order named. He says that the principal lodes to-day are found along the granite-diorite contact and in the irregular fractures in the granite near its border.

It may be that there are contact ore deposits in the district, but in so far as we have observed, the principal mineralization is in the veins which are found in the granite and extending into the pyroxenite-peridotite area.⁴

In the present report the formations are outlined in a simple manner which it is believed will be helpful in the field to those who care to study the general structure of the district. Moreover, it makes possible a tentative discussion of the origin and relations of the ore deposits in so far as now known.

Along the coast there is an irregular belt of pyroxenite with some peridotites which in places are schistose. It extends from Mambulao Bay beyond Paracale to Bagacay Point. These rocks usually are dark colored and have a greenish tinge, some of them being highly serpentinized. The schists often are talcose and make the trails over the area very slippery in places.

Inland from the belt of country just defined there is an area of granite varying from massive to gneissic in texture.⁵ This rock consists

⁴ However, we did not examine all the underground workings in this area.

⁵ This rock and some others of the district were described by Joseph P. Iddings in *The Petrography of Some Igneous Rocks of the Philippines. This Journal, Sec. A (1910), 5, 155.*

of white feldspar and quartz with dark green mica. It is exposed near Mambulao and extends to Paracale and beyond to the Malaguit, in which stream there are some granite rocks forming very small islands.

Bagacay Mountain consists of diorite. It forms the southern part of the district and extends from near the coast, inland almost to the mouth of the Daguit River. The Labo River flows for some distance along its southern boundary.

Inland from the granite area and north of the Bagacay diorite there is a series of sedimentaries consisting of conglomerates, sandstones, shales, and some limestone with intruded andesites. These rocks are well exposed on the beach west of Mambulao and continue southward to the Malaguit River Valley. They are more or less metamorphosed. A limestone of the series converted into marble was seen in the bed of the Malapanay River, a tributary of the Malaguit.

These formations as defined are shown approximately on the accompanying geologic map. In using this classification it should be borne in mind that the detailed structure and exact limits of the areas are not yet known and that rocks from but relatively few localities have been studied microscopically.

The relative ages of the formation of the district have not been determined fully. The pyroxenites are older than the granite, since dikes of the granite can be seen cutting the pyroxenites near Mambulao. From the nature of the rock it may be inferred that the granite did not originally appear at the surface, but has been uncovered by erosion. The relations of the diorite of Bagacay are not clear, but this rock is probably younger than the pyroxenite, since on the lower slopes of Mount Bagacay there are places where the diorite seems to have been intruded through the pyroxenite. The andesites intruded into the Tertiary beds are younger than these sedimentaries, but it should not be inferred that this is true of all the andesites of the region since there is andesitic material in the conglomerate beds of the series. Further conclusions as to the relative age of the formations can not be made at this time.

Ore deposits of the Paracale-Mambulao mineral district.—The granite is cut by many well mineralized quartz veins and a few of these can be traced with a fair degree of certainty into the pyroxenites. At some places where there are veins in the pyroxenite, the granite may occur below.

There are veins in the Bagacay diorite, but thus far no very important ones have been found and they are not known to be continuous into the other rocks. In the area of the sedimentaries and intruded andesites there are a number of well defined veins, but they can not now

be traced into the adjacent formations. The majority of these are quartz, but in the Tumbaga property calcite veins occur, carrying free gold. The calcite may have had its origin from limestones in the sedimentary series.

The ore deposits are not sufficiently studied to make it possible to distinguish different periods of mineralization, but it is quite probable that this can be done as development work progresses. At present the veins related to the granite show the greatest number of old workings and are the most important. The strikes of the veins of the district which were recorded fall between 5° and 40° east of north.

Most of the values of the district are the gold content of the ores. The natives worked in the oxidized zone for free gold. The future development must take into consideration the sulphides. These ores as a rule are highly pyritiferous and contain in the different veins varying amounts of chalcopyrite, galena, and sphalerite. Some of the ores are probably refractory.

Many of the veins are of good width and are persistent, while a few are wide. Usually, smaller ones are associated with the important veins, and some of these are said to carry high values. Definite information as to values in the district is not available for this report. Most of the properties are not developed sufficiently to warrant detailed descriptions.

There is hematite iron ore near Bagacay Point, Calabornay, and at Malii, occurring in the form of boulders. Probably larger deposits can be uncovered at these places. A deposit of iron ore in the form of a dike cutting sedimentaries is found on a small island in Mambulao Bay. It continues on the mainland where there are conspicuous outcrops. The strike is about north 5° west. This ore body has a width of as much as 13 meters at several places. Some smaller outcrops occur near by. The ore is high grade hematite and is a workable deposit containing an immense tonnage.

Placer deposits of the Paracale-Mambulao mineral districts.—It is generally recognized that the gold in placer deposits of the Paracale-Mambulao district has been derived from the veins. The dredging ground is found principally along the Malaguit and Paracale Rivers and their tributaries, the Gumaus, Bulalacao, and Calambayangung Rivers, and perhaps parts of the intervening streams may prove workable. There is some placer gold in nearly all of the small valleys, but the deposits do not warrant dredging operations.

It is interesting in connection with the placer deposits to discuss the probable submergences and emergences of this part of the coast. The bed rock of the dredging ground in places is at a depth of about 18 meters below sea level, although usually it is shallower. The nature

of the bottom gravel indicates that it was deposited by streams flowing above sea level. The upper part of the deposits contains evidences of tidal conditions and some of the streams are tidal for a long distance inland. These facts point to a submergence of the coast. It is believed that this submergence was regional, that it affected the northern coast of Camarines Province and gave the drowned appearance to the shores along Caramuan Peninsula. On the map of the physiographic districts (fig. 1) the 30-fathom line is shown to pass nearly parallel with this coast and outside of the islands lying off the shore. The emergence of the coast, which is indicated by the littoral deposits of the lowland at Daet and to the north, is later and may be local.

Nalasvetan mineral district.—This district is situated about 34 kilometers south 19° west from Mambulao, not far from the watershed of the cordillera, at an elevation of about 300 meters. The mineralization occurs along silicious zones. At this place a considerable amount of mining, practically all by open cuts, was done during the Spanish régime. The country rock is andesite. The locators of the present claims have done the greater part of their prospecting on a big body of ore which extends through Nalasvetan hill for a distance of about 1.5 kilometers, striking north 40° west and standing nearly vertical. The main ore body, as is shown by recently driven tunnels, is about 6 meters wide. It carries free gold and has the characteristics of a large, low-grade deposit. Thus far no sulphides have been encountered. Some manganese oxide is found aside from iron oxide and clay gouge.

Ragay Gulf mineral district.—A considerable area of placer ground has been staked for gold dredging near the head of Ragay Gulf and some tests by boring have been made. Copper ore, principally carbonate, has been found as float near Talcauayan. Farther inland thin beds of coal have been seen and float coal of good quality has been picked up. Placer claims for dredging have been located on the Viñas River and the streams entering Talcauayan Bay. There is gold-bearing gravel along the streams inland from Talcauayan, but it is shallow and in small areas. The rocks just to the east of Talcauayan are termed greenstones in this report. They are cut by quartz porphyries. They have been subjected to dynamic action and the specimens of greenstone could not be determined microscopically. No veins have been opened in them.

Historic eruptions of Mayon.—This volcano, by reason of the number of its eruptions, is considered the most active cone in the Philippines.

Abella, in his monograph written in 1882, gives an account of the historic eruptions, and Padre José Coronas includes a resumé with his account of the eruption in 1897. In chronologic order their characters may be noted as follows:

1616.—Simply a notice of an eruption. 1766.—Eruption, July 20, lasting 6 days. A current of lava is said to have descended the eastern slope. 1800.—Stones, sand, and ashes were thrown out. Some adjacent settlements, Cagasaua, Budiao, and others, were destroyed and some cultivated fields ruined. The last and most violent activity occurred during the closing days of October. 1814.—On February 1 there was a violent eruption. A torrent of "fire, lava, and large hot stones" descended the southern slope of the cone. According to some descriptions, 1,200 dead were collected after the eruption which burned and ruined the towns of Camalig, Cagsaua, and Budio and half of Albay and Guinobatan. 1827.—In June a period of eruption began which lasted until February, 1828 (?). 1835.—An eruption in the month of May. 1845.—An eruption on January 21. 1846.—An eruption of ashes. 1851.—Two small eruptions of ashes. 1853.—An eruption on the 13th of July lasting only a few hours. Ashes fell and a great number of hot stones rolled down the slopes of the volcano, destroying many houses and causing the death of 33 persons. 1855.—An eruption. 1855.—On December 17, ashes fell on the adjacent towns and some lava was poured out. 1871.—A not very violent eruption on December 8. Ashes, sand, and lava were thrown out of the crater. The wind carried the ashes toward Camalig and Guinobatan, forming a layer 4 millimeters thick at these places. Streams of "lava" descended toward Albay and Legaspi. Two persons were suffocated in Bocton and one was burned in Buyuan. 1872.—In September, an eruption occurred which lasted four days. 1873.—An eruption took place lasting from the middle of June until July 22.

1881-1882.—An eruption noted for its length began on July 6, 1881, and lasted until the middle of the next year. It was described by Abella as characterized by the tranquil eruption of lavas from various places near the summit of the cone. The lava issued in a nearly solid state, or it was fragmental and incoherent, but always incandescent. On November 21 and December 14 the eruption was more violent and great quantities of steam and ashes came from the crater. Ashes fell on Camalig and Guinobatan.

1885.—From November 21 to December 2 there was a slight eruption, the materials ejected descending as far as 400 to 600 meters from the summit. 1886-1887.—This period of intermittent eruption began July 8, 1886, when volcanic material descended the south slope of the cone. On February 22 ashes fell in the vicinity of Camalig, and on March 9, ashes fell in Guinobatan. 1888.—Eruption of ashes on the summit of the cone on December 15. 1890.—In September an eruption of little importance. 1891.—Slight eruption in October. 1892.—In the eruption of February of 1892 volcanic materials descended the slopes of the cone. Many inhabitants of Libog and Camalig left those towns in fear, because of the length and violence of the eruption. It is reported that the cone lost 100 meters in height during this period. 1893.—An eruption occurred during October. Volcanic materials descended the slope of the cone to an elevation of about 710 meters, or about the limit of vegetation. 1895.—A slight eruption in July. Some incandescent materials thrown out in November. 1896.—An eruption of little importance began in August, similar to the one of 1895. Incandescent materials were thrown out in September.

1897.—This, the most destructive eruption of Mayon since the year 1841, began May 23. On June 25 and 26 it reached its culmination in a disturbance which lasted 17 hours. The activity then decreased gradually and terminated in July.

The description by Coronas is accompanied by a map showing the line along

which volcanic materials descended the slope of the volcano (fig. 3) and a second map showing the area in which the ashes fell (fig. 4). About 350 people were victims of this disaster. During the first days 212 dead were buried in the vicinity of Libog. Sixty-six were injured and of these, 14 died as a result of

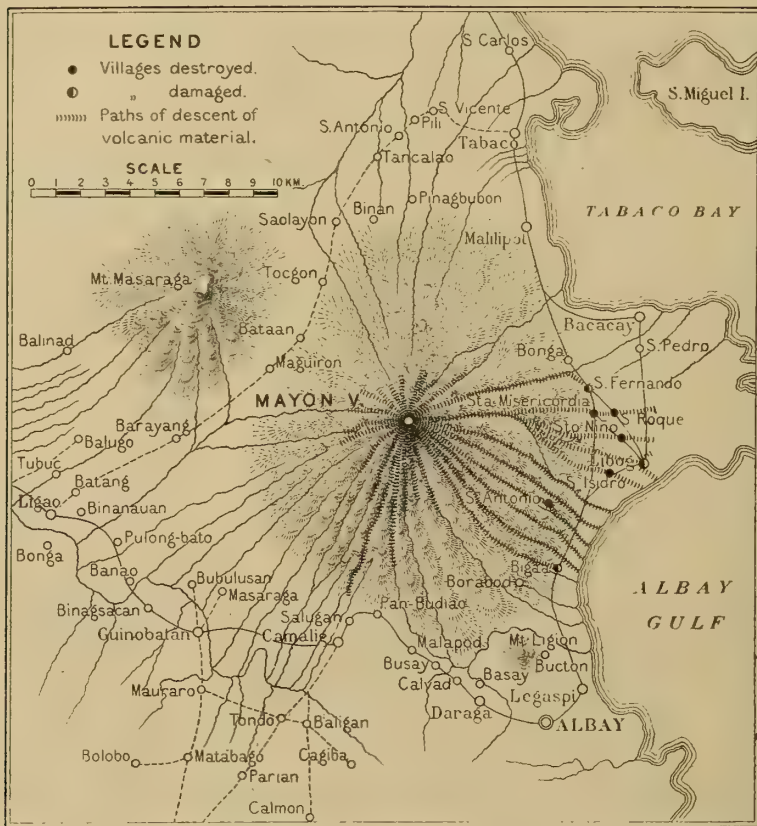


FIG. 3.—Sketch showing the lines of descent of volcanic materials from the slope of Mayon during the eruption of 1897. Taken from a map by Coronas.

burns. Hot ashes fell in Tabaco. According to one report, 50 centimeters of ashes fell in 24 hours in that town, and in Tiui, during the same interval 15 to 20 centimeters. Another report states that 15 centimeters of ashes fell in Tabaco. Small stones (probably lapilli), the size of pigeon eggs, were reported to have fallen in Ligao, and small lapilli in Camalig. In Albay and Daraga, the fall of ashes was about 1 or 2 millimeters and in Legaspi less. In Virac, Catanduanes Island, 5 to 6 centimeters of ashes were reported. The irregular distribution of the ashes and the conflicting statements as to their depths are explained by Coronas as being due to the variation and action of the wind. He believed that the ashes were carried to the east by the lower currents of air and to the west by the upper.

A stream of hot water descended between Libog and Legaspi after the eruption had ceased, and a month later another stream of hot water descended to the

east-northeast, causing the death of an inhabitant near Malipot. Next to Libog, the vicinity of Camalig suffered the most damage as a result of the great quantities of sand and stones which were brought down after the eruption by the floods occasioned by heavy rains.

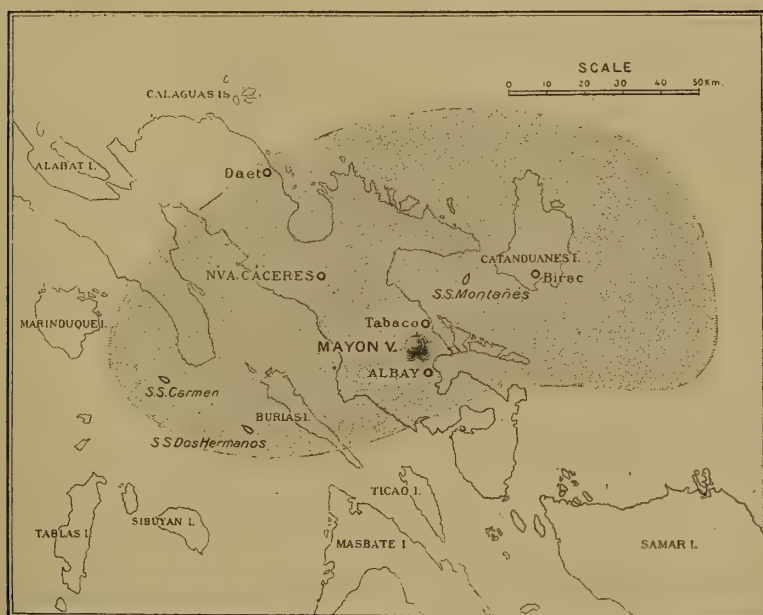


FIG. 4.—Sketch showing the approximate area in which ashes fell during the eruption of Mayon in 1897. Taken from a map by Coronas.

Character of the eruptions of Mayon.—Von Drasche, from his observation of Mayon, concluded that during its periods of activity large quantities of ashes and occasional small lava flows had been erupted from the summit of the volcano.

Abella, in his monograph, cites this opinion and then states that neither the descriptions of former eruptions nor his observation substantiate this conclusion. He says that small quantities of ashes, which are a purely fortuitous or accidental element, are thrown out generally at the commencement of the eruptions, or at the times when they increase in force. On the other hand, during many days or months, large amounts of incandescent lava appear which, although fragmentary and incoherent, flow in an almost constant manner, not only from the summit of the mountain, but from the numerous fissures or subordinate openings, some of the latter being nearly half-way down the slope. He explains that the steep slope and the incoherent character of the materials on the sides of the volcano prevent these subordinate openings from being preserved.

Mayon has been visited lately by many people, and numerous photographs have been taken of its features, but no one has called attention to evidence of former openings or fissures below the summit. Von Drasche seems to have been correct in his statements. Some of the

confusion in regard to the "lava flows" of Mayon probably has resulted from loose usage of the term. During this reconnaissance made around the base of the volcano, special attention was given to the character of the materials which descended during the eruption of 1897. No molten lavas reached the sea or the base of the cone as sometimes has been stated. It is probable that molten lavas issued only from near the summit and seldom descended more than one-third of the slope before cooling. The lower part of the lava flows mapped by Coronas consisted of fragmental materials containing large angular masses of solidified lava. It is reasonable to suppose that most of the ejectamenta fell near the summit of the cone and that the lavas which were poured out cooled on the unstable materials of the slopes of the volcano, and under the influence of gravity the accumulations broke down and descended in the form of rock streams or avalanches while they were still hot and in part incandescent. The lines of the descent were in many cases along the deeply eroded water courses. On Coronas's map, from which text figure 3 is adapted, the paths of descent, called lava flows, correspond in most cases with the drainage.

Tiui Hot Springs.—The most noted hot springs of this region are near Tiui; they have been described by Jagor, von Drasche, and Abella. Abella considered them as subordinate volcanic emanations of Malinao.

Hot water accompanied by sulphurous gas issues at a place termed Jigabo, in the bed of a small stream, the Naga. This place has the nature of a fumorole. The stones in the river bed have been largely decomposed by the chemical action of the waters, and the ground and stones in places are coated with a sulphurous efflorescence. This spot is but a short distance to the west of Tiui. A small bath house has been constructed, and a pit walled up with stones serves as a pool for bathing. The temperature of the bath is regulated by conducting the desired amount of cool water from the stream into the ditch which leads the hot water to the pool. Farther up the stream there is a place where some gases emanate from the ground and the water is somewhat mineralized. Naglagbong, which lies down the stream, is the principal point at which the hot waters of Tiui are found. There is a pool about 20 meters in diameter filled nearly to the rim with water, which steams very slightly. Around it there is a white, silicious deposit which shelves out over the water. The pool is transparent, and in the depths the water has beautiful, blue colorings, and fantastic, silicious deposits may be seen forming the sides of the basin and the narrow, irregular opening in the bottom. There is white, silicious sinter near by, covering a considerable area and grading off into bluish mud. Many minute cracks and vents occur in the sinter, from which small quantities of sulphurous gas, mixed with steam, arise.

The water near by in the shallow pools is hot, and bubbles of gas break on its surface at some places. The silicious sinter has been built up in a low, irregular, convex area on which there is what is termed the white cone. This place at one time must have contained a central opening in which the hot waters arose. The silica deposited from the water gradually built a rim around the opening and then sealed its mouth, leaving a small basin-like depression on the top. To the northwest on the white cone, there is another large pool of hot water and beyond

it the deposits are tinged and in part vividly colored with red oxide of iron. Fantastic forms of the silicious material may be seen simulating coral growth. Foreign substances which have accumulated near the hot waters are coated with the sinter.

Lanot Mineral Spring.—On the beach at the *barrio* of Lanot on the west coast of San Miguel Bay there is a spring which contains iron and is highly charged with carbon dioxide gas. The waters are considered to be of medicinal value and the place is a local health resort.

In addition to the springs above mentioned, attention may be called to the hot springs near Manito, across the bay from Legaspi. One of these on the beach is covered at high tide, but at low water it sends up a small column of steam which can sometimes be seen from passing steamships. There are other hot waters and a number of mineral springs in the region of the cordillera, but they are considered of little importance at present.

CARAMUAN PENINSULA.

This area has been but partially studied. The eastern end consists principally of Tertiary sedimentaries which have been folded and much disturbed from their original positions. Rugged topography is produced by the upturned limestones which have weathered into steep hills. The rocks have been subjected to strong dynamic action, are considerably metamorphosed, and in places exhibit a schistose structure.

Exposures of schist are found near Sabang at the head of Lagonoy Gulf and the streams bring down schistose andesites from the higher hills. There are somewhat altered schistose andesites near Balochaloc Point on San Miguel Bay. The higher mountains of the peninsula near Saddle Peak have not been studied, but it is inferred from stream gravels that they are andesites.

Dynamic action seems to have been strongest along the southern border of the peninsula, since the sediments near the Caramuan River and on some of the islands near its mouth are less metamorphosed than on the opposite coast. It is probable that the formations of Caramuan Peninsula received a thrust from the Pacific side which folded the sedimentaries and produced the schistose structure in the rocks.

In discussing the physiography of this district attention was called to the drowned appearance of the north coast of the peninsula and to the fact that the 30-fathom line indicates a submarine shelf lying off shore. In explaining the origin of the placer deposit of the Paracale-Mambulao district, additional proof of a submergence was deduced.

The only economic deposits reported as occurring on the peninsula are coal and copper. Coal near Mount Hanopol, which has been prospected by means of a tunnel, was examined and found to be a thin

vertical bed not of economic importance. It is situated southwest of Caramuan. This is the only place at which coal was seen, although the other reported occurrences were visited.

On certain published maps the presence of copper is indicated near the eastern end of the peninsula. When the reconnaissance of this area was made, nothing could be learned concerning copper at the place shown on the map, but it was reported that some copper occurs near Sipaco, which is in the central part of the northern coast.

BATAN ISLAND CHAIN.

The Batan chain of islands includes San Miguel, Cacararay, Batan, and Rapu-Rapu; it is so named in this paper for the reason that Batan Island is the best known of the group because of its coal deposits. San Miguel Island was discussed by Roth who reported that it contained dolerite rocks, similar to those of Malinao Volcano, and also tuffs. Von Drasche, on the strength of Roth's statements, mapped the island as dolerite tuff.

Batan Island has been studied by Smith⁶ whose report is accompanied by a geologic map showing the coal outcrops. The island is described as consisting principally of Tertiary sedimentaries, while an area of pre-Tertiary igneous rocks forms its eastern end and also is indicated on the west end of Rapu-Rapu, and the Tertiary is likewise indicated on the coast of Cacararay adjacent to Batan.

The igneous rock on the east end of Batan is described as a peridotite grading into a pyroxenite. In the text of the report, igneous rocks are noted as occurring in small exposures near Caracaran and Ligan. For a fuller discussion of the structure of the island, readers are referred to the original report. For the purposes of the present paper the general geologic conditions may briefly be outlined as follows:

The Tertiary beds were laid down upon the igneous rocks. In the base of the sedimentaries there is in places a conglomerate formation containing quartz and pebbles and boulders of iron ore. The higher beds are shales, grits, sandstones, and limestones with intercalated beds of coal. There is considerable evidence of disturbance of the strata, especially near the west end of the island, but the details of the folding and faulting have not been worked out.

The Batan Island chain, as indicated by the structure of the islands and the thickness of the sedimentaries exposed on their coast, is probably a fault block. Whether the stratified formations were once continuous with some of the adjacent areas of the same age is not certain, but it is probable that they were, and that the emergence of this chain was concomitant with the submergence and erosion of extensive Tertiary deposits on the eastern flank of the cordillera.

⁶ The Coal Deposits of Batan Island, etc. *Bull. P. I. Min. Bur.* (1905), No. 5.

Coal.—The coal deposits of Batan Island are the best developed of any in the Philippines. A detailed account of the outcrops may be found in Smith's report.

RAGAY COAST HILLS.

This area is occupied by Tertiary sedimentaries with the exception of a small strip of the coast north of Pasacao which contains igneous rocks. Von Drasche mapped a part of the territory as younger coral-line limestone and near Pasacao indicated older crystallines in the locality of the igneous rocks which Roth had described from Jagor's specimens and notes.

The most interesting of the igneous rocks is a diorite which in part is gneissic and schistose. Von Drasche calls attention to the importance of determining the relations of the sedimentary beds at this point, since if they overlie the diorite, it indicates that the crystalline schists form the base of all the other formations in southern Luzon. From the field relations it is certain that this diorite is older than the limestone near by, but it does not follow that the basis of all of the younger rocks are crystallines containing diorite.

At the northern end of the area there is basalt, and some associated rocks, difficult to determine because decomposed, but probably basaltic or andesitic. A hot spring issues at some distance from the good exposures of basalt near the mouth of the Tinalmud River. On Refugio Island, south of Pasacao, there is basalt and on the shore opposite hot springs occur. These basalts may be rather recent intrusions since there are hot waters near them. The field relations are not clear.

Von Drasche concluded that the form of Mount Bantuin as he saw it from the mouth of the Ragay River indicates it to be of volcanic origin. When seen from other points it does not have the form of a rounded cone, and close examination proves it to contain sedimentaries, some of the limestone being conspicuous.

The sedimentaries of the Ragay Coast Hills are principally limestones with some sandstone and conglomerates and coal aggregating more than 1,000 meters. The exposures of the limestones are the more conspicuous since they form ledges and escarpments. In general, the dip of the beds is toward the Ragay Coast, but there are minor folds and local disturbances in many places. A noted exception is Mount Bernacci or Amtig which has a monoclinical structure, the beds dipping a few degrees to the northeast.

The conglomerate beds contain boulders of andesite and basalt, and rarely of diorite or other igneous rocks. They are nearly all in the basal part of the series and indicate adjacent land areas. Such low-lying land areas containing igneous rock, which furnished sediments, probably existed during the earlier stage of deposition. As deposition progressed and the coralline limestones were formed, the seas must have been clearer.

It is probable that subsidence was in progress, since the mass of limestones has a thickness far greater than the depth of water in which corals live. The elevation of the series of sediments to their present position was brought about by the growth of the cordillera, on the western flank of which they lie.

Coal.—Von Drasche cites the occurrence of unimportant indications of coal in the Ragay Hills about 9 kilometers southwest of Bato Lake and states that the importance of this locality, called "Mines of Batac," is overestimated. The history of the discovery of this coal can be found in Burritt's compilation on the Coal Measures of the Philippines. The thickness of the bed is stated to be from 2 to 8 centimeters. The dip is 60° in the direction south 70° west. Float coal is reported at a number of places along the coast, but no prospecting has been done that has discovered workable beds.

BICOL VALLEY.

The surface formation of the lowland along the Bicol Valley is nearly everywhere alluvial. It consists of materials brought from the volcanics of the Southeastern Cordillera and the sedimentaries of the Ragay Coast Hills. Near the head of the valley there is considerable material that has been washed down from the slopes of Mayon and has aggraded the surface.

At some places where excavations have been made, beds of shells have been found, and in drilling artesian wells shells have been encountered at considerable depths. The character of the formations indicates that brackish water conditions prevailed over the lower part of the valley. South of Bato Lake no wells have been drilled and information accordingly is not obtainable concerning the deeper lying beds. The tide affects the Bicol River up to Bato Lake and formerly it may have reached farther. In fact, it seems probable that during a former time when Mayon Volcano was still in its younger stages of growth, a strait extended from San Miguel Bay to Albay Gulf.

An arm of the formation found in the Bicol Valley extends to Ragay Gulf at Pasacao through a gap in the coast hills which may once have been a seaway.

EASTERN CORDILLERA.

The portion of the Eastern Cordillera represented in Tayabas Peninsula is its southern termination and does not show the typical geologic features which are found much farther north, where it contains high mountains of eruptive rocks and has a rugged topography. In the part shown on the accompanying geologic map the cordillera is formed of folded and faulted Tertiary sedimentaries with the exception of a small area of diorite near Peris. The diorite occurs in a hill and represents a part of the igneous formation which gradually was covered by the strati-

fied beds. Another area of the basal formation is found near Talcauayan Bay and consists of greenstones and quartz porphyry. Materials from it, especially pieces of quartz, occur in the Tertiary conglomerate beds along the Viñas River. There are conglomerate beds at many places near the base of the section of the sedimentaries. They may be seen well exposed on the road from Atimonan to Gumaca and contain boulders of diorite, andesite, and basalt.

Strong dynamic action has produced a schistose structure in the rocks west of Atimonan. This locality was shown on the geologic map of southwestern Luzon. In the Tayabas Peninsula no exposures of schists were seen. Some small pieces were brought to the division of mines, Bureau of Science, from near the end of the peninsula, but the locality was not definitely reported. The dynamic action which developed schistose structure in the igneous rocks seems to have resulted only in folding and faulting of the sedimentaries. As a result of the inclination of the beds the more resistant ones form ridges upon weathering. The strike of the ridges is northwest and southeast with the direction of the peninsula.

Coal.—No workable coal has thus far been reported from the area under discussion. The history of the discovery of the deposits near Atimonan and on Pagbilao Island is given in detail in Burritt's compilation. On D'Almonte's map, coal is indicated as occurring on Alabat Island, but no effort has been made to mine it and it probably is of minor importance.

Petroleum.—In July, 1909, George I. Adams made a reconnaissance in the Tayabas Peninsula and secured samples of oil; these were collected with especial care for the purpose of analysis in the laboratory of the Bureau of Science. The collecting of these samples was one of the important aims of the trip, since the analysis of samples submitted by private persons showed the oil to be of such a high grade that capitalists were not willing to believe it to be a natural oil and, accordingly, would not take an interest in developing the field.

The crude petroleum from Tayabas Peninsula has a very low specific gravity and only two or three fields in the world produce an oil comparable with it.⁷ It is very desirable for distillation since it contains an unusually high percentage of gasoline and kerosene and accordingly it should command a high price in the market.

Up to the time of the reconnaissance a considerable amount of prospecting had been carried on in a quiet way, and some wells had been drilled to shallow depths with encouraging results, but very little information concerning the oil finds had reached the public. During the reconnaissance, oil-seeps were seen in three distinct localities. A place occurs on the Ajus

⁷ For analysis of the oil, see *Tayabas Petroleum*, by G. F. Richmond. *This Journal*, Sec. A (1910), 5, 1.

River which reaches the coast between Catanauan and Mulanay, where a pole or bar is sunk into the water and causes oil to rise to the surface and flow down the stream, forming patches which are distinctly visible. At this place, mining locations had been made recently. The second locality where oil-seeps were seen is in the valley of the Vigo River. The oil accompanied by some gas rises to the surface when a bar is thrust into the bed of the stream, and this fact led to the drilling of a shallow well near by, by which means some oil was encountered. There are several similar seeps in this valley. These have not been prospected. Nearly the entire valley of the Vigo River has been staked as oil claims.

There is a place on the Bahay River where at any time the oil may be seen rising to the surface of the water and floating down the stream, and close to this point there is a well about 35 meters deep in which a fair showing of the oil was encountered. The valley of the Bahay River is likewise staked as oil claims. Seeps and small gas vents are known at many other places, so that the territory which may be prospected is large; in fact the whole peninsula is worthy of investigation.

The study of the geologic formation demonstrated that the peninsula is anticlinal in structure. However, it should not be inferred that it is a perfect anticline, but rather a grand upward flexing of the sandstones, shales, and limestones of Tertiary age which has resulted in some places in faulting and a repetition of the beds. The shales are in part highly carbonaceous and the sandstones are suitable as reservoirs for oil and gas. The total thickness of the beds undoubtedly will aggregate more than 1,000 meters. The higher formations in general are the limestones which form ridges running from northwest to southeast with the trend of the peninsula. The sandstones and shales outcrop in the intermediate areas. There are many good exposures along the beds of the streams and in some cases on the higher slopes, but the ridges are covered with timber and the rolling country with *cogon* grass, so that it would require careful study to work out the details of the structure. In some cases the dip of the beds is 45° or more. Aside from looking for showings of gas and oil, the prospector should study the dip of the rocks and find an area where the beds dip at relatively low angles in order to have favorable conditions for the development of the field by drilling.

Transportation to Tayabas Peninsula is not difficult, although it is rather indirect. At present a contract steamship calls at Catanauan at intervals of ten days and there are several freight vessels which stop irregularly at this and other ports. The trails are suitable for foot travel during the dry weather. During the rainy season it would be well to use carabaos, and usually these can be obtained without much difficulty. From Catanauan the peninsula may be crossed by trail to San Narciso, but the easier route for visiting the prospects above men-

tioned is along the coast from Catanauan to Mulanay and the Ayoni Valley and thence across to the Vigo River, following down that stream and then along the coast southward to the Bahay River. The usual time required to go from Catanauan to the Bahay River would be three days, travelling with carabaos. The oil showings in the Tayabas Peninsula are fully as important as some which have led to the bringing in of successful wells and the exploiting of large fields in the United States.

At the date of writing the present report, the Bahay Valley Oil Company has a standard rig located on its property and is drilling.⁸

VIÑAS LOWLAND.

The geologic formations of this physiographic district are Tertiary sedimentaries with some alluvial and littoral deposits. The character of the Tertiary formations has already been described sufficiently in discussing the Eastern Cordillera. The alluvial deposits are found along the valleys which drain the lowland. The rivers are tidal, but are not bordered by very extensive bottom lands and in many places there are low hills on the banks. The littoral deposits are narrow.

Von Drasche mapped a belt of alluvium with raised calcareous beds and marls with recent shells between the head of Ragay Gulf and Calauag Bay. It was his idea that this isthmus had been a strait in geologically young time.

From the exposures seen while making the reconnaissance for this report it is fairly certain that the formations on the isthmus belong to the series which is classed as Tertiary. No shore lines of a former strait were seen and no recent marine deposits were found. The conclusion was reached that the area is now lower than formerly. It is probable that with the growth in elevation of the Eastern and South-eastern Cordilleras there has been in the intermediate zone submergence which has produced the tidal conditions of the rivers of the isthmus.

GATBO UPLAND.

This minor subdivision is formed by a remnant of the Tertiary formations. There are some raised coral beaches on its seaward margins. In the eastern part of the area the Tertiary beds dip slightly to the

⁸ More detailed examination of the Tayabas oil district, made by one of the writers subsequent to the work done for this report, revealed two outcrops of igneous rock near the eastern coast of the peninsula, one several kilometers below the oil seep on the Vigo River, the other farther north, just west of San Narciso. The rock is a typical andesitic agglomerate and apparently forms the core of the high ridge which borders the eastern coast in this locality. The flanking sedimentary strata are locally much disturbed, and dip steeply away from the axis of the ridge. The discovery of this igneous formation does not alter the general conclusions already drawn concerning the district as a whole, but it is evidence which should be considered in locating drill holes.

northeastward. On the western margin the beds are upturned. Coal is found in this upturned portion.

Coal.—The coal at Gatbo mentioned in Burritt's report as being at Sugud, became the property of a Spanish stock company, "La Paz," in 1874. The Spanish Government donated to this company the services of José Centeno, chief of the inspection of mines, and during the next two years, according to Centeno's report, extensive development work was carried out. Little evidence of this development work remains to-day. The grade for an old tramway may still be traced, leading from a small wharf at Gatbo to a caved-in shaft several kilometers to the southwest. Near this shaft are the ruins of an old *camarin* in which stands a small masonry engine-base. A true outcrop of the coal seam occurs in the bed of an adjacent creek, and, directly across this creek from the old shaft, the seam has been reopened by a tunnel about 10 meters long, probably the work of recent prospectors. The coal is shown to dip vertically and strike north 28° west. Its apparent width is 2 meters. The coal in the tunnel contains "horses" of shale. Other outcrops may be seen near Gatbo. They are all impure, with lenses of shale and clay.

These coal outcrops indicate thick coal beds. The dip, if constant with depth, is not a serious disadvantage. If Centeno's report be accepted, the property undoubtedly is susceptible of being mined. If Centeno's report be ignored, the coal still merits thorough exploration. It seems probable that displacement through faulting would be met with in extensive development. It may be pointed out that such a difficulty would be less serious with a vertical bed than with one more nearly horizontal.

SORSOGON LOWLAND.

The greater part of this area is covered with unconsolidated materials which have been derived from the adjacent highlands, or with volcanic tuff and pumice which probably were deposited in the sea at a time when the isthmus was submerged.

The underlying formations were seen, poorly exposed on the road from Sorsogon to Gubat where some cuts have been made. They are limestones and decomposed igneous rocks which perhaps are andesites. It is probable that the Tertiary formations of the Gatbo upland continue for some distance under the surface deposits of this area.

There are narrow littoral deposits on the borders of the area which are not shown on the geologic map, and there is considerable alluvium at the mouth of the river which passes Juban.

BULAN COASTAL PLAIN.

The formation of this plain consists of tuff and pumice which probably was deposited in the sea. The exposures seen in the low sea cliffs

between Bulan and Magallanes show the character of the deposit and exhibit some bedding. Inland, the plain is aggraded by detrital materials. Bulusan Volcano was undoubtedly the source of much of the tuff and pumice.

MINERAL RESOURCES.

No new mining localities have been discovered in southeastern Luzon during recent years, but since American occupation considerable development work has been done and prospecting has been carried on at nearly every place concerning which there were either records or traditions of economic deposits.

The history of gold mining in the Paracale-Mambulao district covers a long period and contains much of the glamour that usually is found in the accounts of the wealth of old Spanish mines. Most of the recent locations on lodes include old workings. Similarly, the Nalasvetan locality and Catanduanes Island have been investigated and prospected as a result of information obtained from the inhabitants. However, the placer locations are not confined to the ground where gold was formerly washed by the natives, since present dredging methods make it possible to obtain values from areas which could not be worked by them.

The present mining enterprises are the result of new energy and larger capital, and the future development is dependent upon the introduction of further capital. The natives worked only the free gold. Future mining must take into consideration the sulphide ores.

The history of coal mining compiled by Burritt mentions practically all of the localities where coal deposits are known to-day. The presence of oil-seeps was known by the inhabitants of Tayabas Peninsula and they collected small quantities to burn for lights, but prospecting by means of drills was never attempted by them.

The geologic relations of the economic deposits have been discussed in a former chapter. The following is a brief résumé of the condition of development of the resources.

Gold.—According to the statistics published by the division of mines, Bureau of Science, the gold production in 1907 was 100 ounces, in 1908 it was 3,470 ounces, and in 1909, 7,223 ounces. Practically all of the production for 1907 was obtained by panning, but during the last two years the increase has been from the dredges.

Silver.—No mining is carried on for silver, but some is obtained alloyed with the gold which is produced, and the lead ores in some of the veins of the Paracale-Mambulao district are silver bearing.

Copper.—Native copper (tumbaga) is found in the placer deposit at Calbornay. It has been described by Rinne, but his writings are not

in the Bureau of Science library. The copper has a roughened, sometimes crystalline appearance as if it had been deposited in the placer ground and certain of the miners in the district think that it has been precipitated from solution on the iron in the placer.⁹ There is more or less copper associated with the other sulphides in the veins of the Paracale district. Near Talcauayan Bay on the head of Ragay Gulf, float copper ore has been found which consists largely of carbonates. Copper ore is said to occur near Sipaco on Caramuan Peninsula.

Lead and zinc.—A number of the veins in the Paracale district carry some galena and sphalerite together with other sulphides. Such ores probably are refractory.

Mercury.—Small quantities of mercury are reported to have been collected in the crater of Isarog Volcano. It is found in depressions in the rocks along the stream courses. No cinnabar has been found.

Coal.—The East Batan Coal Company has developed a mine near the *barrio* of Batan on Batan Island. The coal bed is 1.7 meters thick and dips to the north at an angle of 13° from the horizontal. The roof of the coal is a shale which does not stand well, and when drawn to make the entries 2 meters high, heavy timbering is required. The coal is sub-bituminous, similar to the other coals of the Philippines.

The United States Army has a coal land reservation which includes the west end of Batan Island. The mine openings are near Liguan, where a pier has been built to facilitate the loading of coal. Mining was begun in 1907 and a considerable amount of equipment has been installed gradually. The coal on the west end of Batan Island is of better quality than on the east end, but where opened it is squeezed and faulted to such an extent that none of the workings made on the various outcrops have thus far developed into a successful mine.

Some prospecting has been carried on at Gatbo where a mine was worked under the Spanish régime, and the deposits on Rapu-Rapu and Catanduanes Islands have been investigated, but no mining operations are in progress outside of Batan Island.

Petroleum.—The occurrence of petroleum in Tayabas Peninsula has been discussed under the geology of the Eastern Cordillera. This is the only part of southeastern Luzon from which authentic reports of the occurrence of petroleum have come.

Stone.—Formerly a considerable amount of stone was dressed and used locally in constructing buildings and bridges and some of it was shipped as ballast in sailing vessels to points where no stone was available. Volcanic tuff was brought from Manila and also some granite which came from Hongkong. Stone is now used only for surfacing

⁹ Rinne thought that the metallic copper had been reduced by organic matter in the placer. The shape of some of the copper specimens suggests plant forms.

roads and in concrete construction. A number of quarries have been opened by the district engineers. A large amount of gravel from the rivers is also used.

Clay.—Native pottery is made at the *barrio* of Bolo near Tiui. The clay employed has been formed by the disintegration of a gray pumiceous stone which contains yellowish mica, some specks of which are seen in the finished ware. Pottery is made also in the *barrios* of Gubat from a clay which also contains mica and is somewhat similar in character to that at Bolo. Alluvial clay is used in Saban, a *barrio* of Oas, and in a *barrio* just north of Libmanan.

The silicious clays at Tiui Hot Springs are used for painting the white designs on the pottery made at Bolo. The red coating is given to some of the pottery by washing it with ferruginous clay obtained from near Buhi.

A white clay resembling kaolin is found near the San Vicente *barrio* of Tinambac and is used for preparing a kind of cold water paint.

Salt.—At many of the coast settlements small quantities of salt are made in a desultory manner by evaporating sea-water. On Calagua Island salt making is carried on as an industry. However, the greater part of the salt used is imported. In some places where sea-water is not available and the nipa palm grows, this plant is burned and the ashes are leached and then evaporated to obtain salt.

Artesian and deep tubular wells.—Wells have been sunk with jet rigs in the Bicol Valley in Camarines Province, at the towns of Nueva Caceres, Bato, Buhi, Nabua, Calabanga, San Fernando, Milaor, and Camaligan. The Province of Albay contemplates the drilling of wells in the upper part of the same valley, in a portion of which the conditions are favorable for using a jet rig.

The use of water from the wells already drilled has been found valuable in combating occasional outbreaks of cholera and improving general health conditions.

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ILLUSTRATIONS.

PLATE I.

Sketch showing the geologic mapping of southeastern Luzon, by von Drasche.

PLATE II.

Mayon Volcano, photographed from a distance of fifteen kilometers from its summit. Legaspi in the foreground.

PLATE III.

Part of the crater rim of Mayon. (Photograph by Martin.)

PLATE IV.

- FIG. 1. Portion of inner wall of the crater of Mayon. (Photograph by Martin.)
2. Looking up a gulch near the summit of Mayon. (Photograph by Brown.)

PLATE V.

- FIG. 1. Slope of Mayon showing lava beds. (Photograph by Brown.)
2. Slope of Mayon showing detrital material. (Photograph by Martin.)

PLATE VI.

- FIG. 1. Pool of hot water with silicious sinter border. Tiui Hot Springs. (Photograph by Alga.)
2. Silicious terraces and pile of foreign materials with silicious cutting. Tiui Hot Springs. (Photograph by Alga.)

MAP.

- Geologic reconnaissance map of southeastern Luzon.

TEXT FIGURES.

- FIG. 1. Index map showing physiographic regions of Luzon.
2. Physiographic divisions of Southeastern Luzon.
3. Sketch showing the lines of descent of volcanic materials from the slope of Mayon during the eruption of 1897. Taken from a map by Coronas.
4. Sketch showing the approximate area in which ashes fell during the eruption of Mayon in 1897. Taken from a map by Coronas.

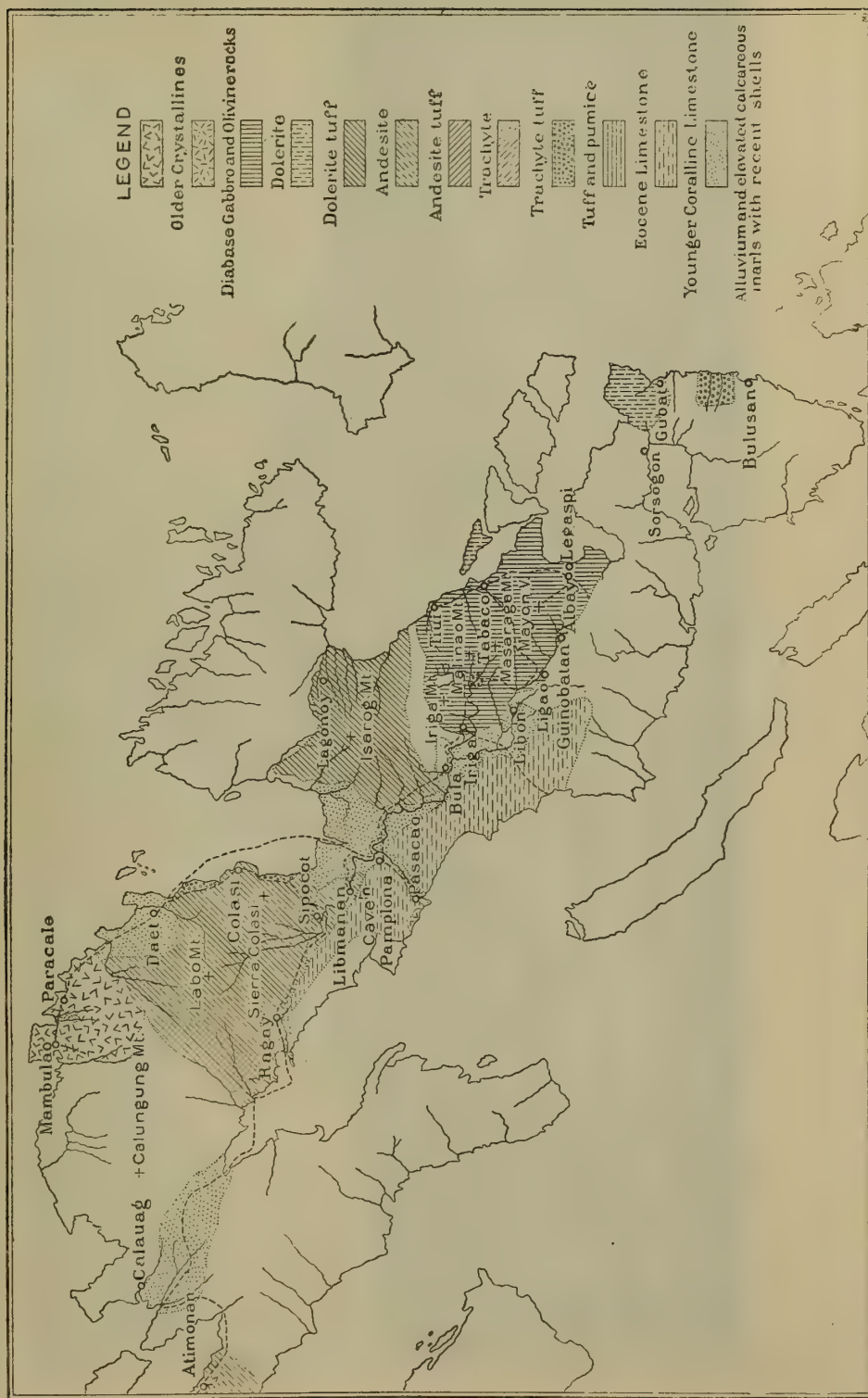


PLATE I.



PLATE II.

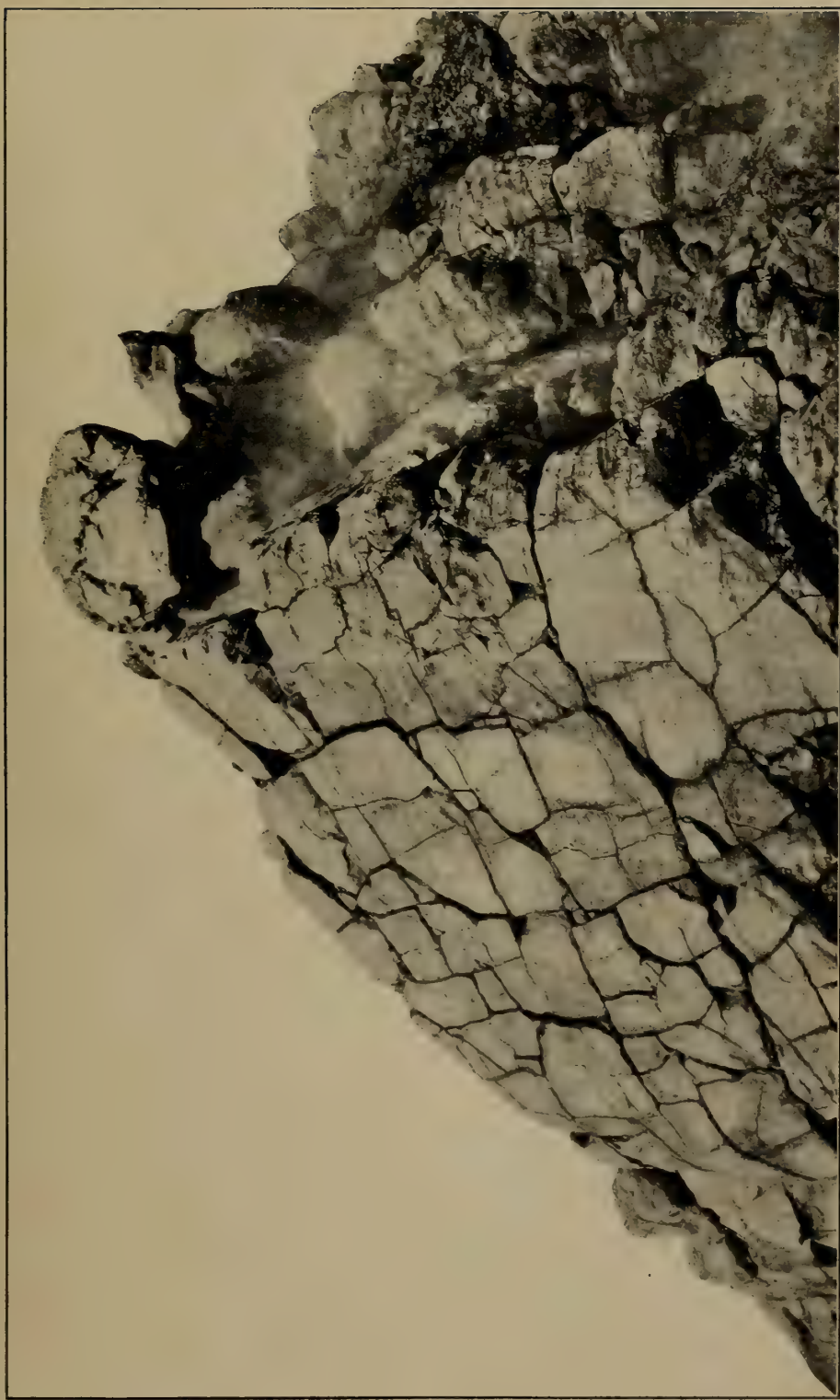


PLATE III.

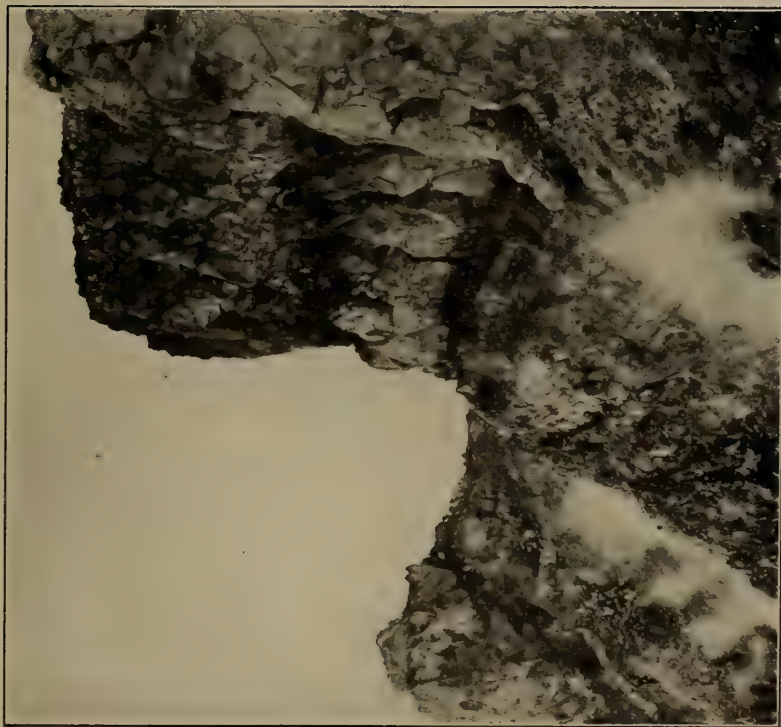


Fig. 1.



Fig. 2.

PLATE IV.



Fig. 1.



Fig. 2.



Fig. 1.



Fig. 2.

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